CORPS OF ENGINEERS, U. S. ARMY

THE ATCHAFALAYA RIVER STUDY

A REPORT BASED UPON ENGINEERING AND GEOLOGICAL STUDIES OF THE ENLARGEMENT OF OLD AND ATCHAFALAYA RIVERS

INCLUDING

PROFILES AND SECTIONS TOGETHER WITH FACTUAL DATA WHICH INDICATE THE PAST RATE AND EXTENT OF PROGRESSIVE CHANGES IN OLD AND ATCHAFALAYA RIVERS FROM THEIR HEAD THROUGH GRAND AND SIX MILE LAKES TO THE SEA

ALL OF WHICH INDICATE THE

PROBABLE CAPTURE OF THE MISSISSIPPI RIVER BY THE ATCHAFALAYA RIVER

PREPARED UNDER THE DIRECTION OF
BRIGADIER GENERAL P. A. FERINGA, C. E.
PRESIDENT, MISSISSIPPI RIVER COMMISSION

BY

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FOR THE

MISSISSIPPI RIVER COMMISSION
VICKSBURG, MISSISSIPPI

ARMY-MRC VICKSBURG, MISS.

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MISSISSIPPI RIVER COMMISSION

(Created by Act of Congress approved 28 June 1879)

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CONTENTS

Volume 1

CONTENTS

Volume 2

CONTENTS

CONTENTS

CONTENTS

CONTENTS

Volume 3

CONTENTS

CONTENTS

ATCHAFALAYA RIVER
(1950 Mileage)

Locality	Miles Below Head
Head of Atchafalaya River	0
Simmesport, La. (gage and L. & A. bridge)	4.9
Odenburg, La.	9.2
Jacoby, La.	10.9
McCrea, La.	12.7
Woodside, La.	14.3
Cypress Point, La.	14.4
Neita, La.	16.8
Bayou Current, La.	20.1
Elba, La.	24.7
Bayou Latenache	26.2
Upper Guide Levee) Morganza Floodway)	27.2
Melville, La. (gage and T. & P. bridge)	29.4
Red Cross, La.	29.4
Melville Crevasse, La.	29.6
Krotz Springs, La. (U.S. Geo. Sur. gage and highway bridge)	40.4
Krotz Springs, La. (and N.O.T. & M. (Mo. Pac.) railway bridge and railroad gage on pier)	40.9
East Krotz Springs, La.	41.2
Alabama Bayou	42.6
Bayou Courtableau	48.3
Alabama Bayou and head of Whiskey Bay Pilot Channel	54.4
High line and abandoned Sou. Pac. R.R (Whiskey Bay Pilot Channel)	57.6
Atchafalaya, La., and abandoned S.P.R.R.	58.8
Upper end Butte La Rose Cutoff	61.2
Lower end Whiskey Bay Cut	64.0
Butte La Rose	64.5
Upper end Blind Tensas Cut	67.9
Splice Island	71.0
Lake Mongoulois (center)	72.3
Jakes Bayou	72.8
Upper end Bayou Chene Cut	74.2
Bayou Chene, La.	75.4
Tarleton Bayou	75.9
Big Bayou Chene	77.0
Upper end Lake Chicot	77.8
Bayou Sorrel	78.7
Hog Island	82.2
Keelboat Pass gage	84.4
Lower end Keelboat Pass and upper end Grand Lake	85.0
Little Bayou Pigeon	88.6
Charenton Reach and gage and floodgate	92.8
Big Bayou Pigeon	93.4
Myette Point (upper end of cut)	95.4
Miller Point	99.4

ATCHAFALAYA RIVER
(1950 Mileage—Cont'd)

Locality	Miles Below Head
Windy Point	101.8
Six Mile Lake	102.5
Cypress Pass (upper end) and Cypress Island	102.7
~~Verdunville Canal and gage~~	103.8
Wax Lake Outlet	105.5
Lower Atchafalaya River (old opening)	108.3
Stouts Pass (upper end) and Flat Lake	112.5
Drews Island	113.5
Drews Pass	114.5
Lower Atchafalaya River and Berwick floodgate	114.8
Morgan City highway bridge	116.3
Morgan City, La., and Berwick, La.	116.5
Southern Pacific R.R. bridge and gage	116.6
Bayou Boeuf and Intracoastal Waterway (Gulf section)	116.8
Bateman Island (upper end)	117.0
Intracoastal Waterway (Gulf section), west bank	119.6
Bayou Shaffer	125.4
Shell Island Point	132.2
Gulf of Mexico (Atchafalaya Bay)	135.4

SYLLABUS

Section 8 of the Flood Control Act approved May 15, 1928, states that: "The project herein authorized shall be prosecuted by the Mississippi River Commission under the direction of the Secretary of War and supervision of the Chief of Engineers."

The plan authorized by the above act provides for the control of the maximum probable flood that may occur in the Lower Mississippi Valley. The Mississippi River watershed is the largest drainage basin in the United States and the maximum probable flood in the latitude of Old River has been determined under the project as 3,000,000 cubic feet per second. This flood flow is to be routed to the sea by passing 900,000 cubic feet per second from the Red River backwater area into the Atchafalaya Basin at the latitude of Simmesport. Of the latter amount, a discharge of 650,000 cubic feet per second is to enter the Atchafalaya Basin through the main channel of the Atchafalaya River and a discharge of 250,000 cubic feet per second is to pass down through the West Atchafalaya Floodway. A discharge of 2,100,000 cubic feet per second is to be carried down the Mississippi River to the head of the Morganza Floodway, where a discharge of 600,000 cubic feet per second is to be diverted through the Morganza control structure into the Atchafalaya Basin.

The Mississippi River below the Morganza control structure is to carry a discharge of 1,500,000 cubic feet per second to the head of the Bonnet Carre Floodway, where a discharge of 250,000 cubic feet per second is to be diverted into Lake Pontchartrain. The remaining water, 1,250,000 cubic feet per second, is to be carried down the Mississippi River into the Gulf of Mexico.

The Chief of Engineers, U. S. Army, in letter dated 29 September 1950, subject: "Atchafalaya River Study," directed that the Mississippi River Commission prepare an engineering study of the rate and extent of the enlargement of the Atchafalaya River and its connecting link, Old River.

This report finds that: (1) the Atchafalaya and Old Rivers have enlarged their channel capacities to such an extent that a discharge of from 50,000 to 100,000 cubic feet per second in excess of the project requirement for these streams can be discharged when project flood elevations occur at Simmesport, Louisiana; (2) the Atchafalaya and Old Rivers are continuing to enlarge and will, at their present rate of enlargement, capture the Mississippi River unless prevented by man-made structures; (3) the Atchafalaya-Old River channel will probably become the master stream in about 25 years unless restricted by regulating works; (4) the heavy sediment load being deposited below the unleveed channel will make it necessary to assist the Atchafalaya River in the development of an efficient single channel in the lower basin in order to pass necessary high-water flows. These improvements will tend to increase the rate of diversion, and any regulating structures should be commenced before or concurrently with improvement dredging in the lower basin; and (5) the Wax Lake Outlet is capable of passing the discharge for which it was designed but should eventually be improved to pass a somewhat larger discharge.

DIRECTIVE

The Lower Mississippi River, its tributaries and distributaries, especially the Old and Atchafalaya Rivers, have been under study by the Corps of Engineers and the Mississippi River Commission for some 100 years, and a tremendous amount of data has been collected and is available. All available engineering information on the changes in the carrying capacity and alignment of the Atchafalaya and Old Rivers is to be thoroughly studied, and the geology of the Atchafalaya Basin, together with its probable effect on the river's future regimen, is to be used to complement the engineering report for future planning. All phases of river hydraulics are to be thoroughly analyzed. Factual data on the rate and extent of progressive changes in bank lines and sections of Old River and the Atchafalaya River from its head through Grand and Six Mile Lakes to the Gulf of Mexico below Morgan City, Louisiana, together with rate and amount of deposition in the lake region of the lower Atchafalaya and the leveed portion of the upper Atchafalaya River, are to be analyzed and presented in a suitable manner. The effectiveness of the Wax Lake Outlet in discharging excess waters from the lower Atchafalaya Basin is also to be considered in the study.

In accordance with these directives, the engineering portion of the study has been comprehensive, thorough, and complete, and has made full use of all available historic and current engineering data, with such additional surveys as were needed to establish existing conditions within the basin and the adjacent Mississippi River.

The geological portion of the study has procured such geological data as were obtainable in the time available, but will also utilize such additional time as is definitely necessary to make it full and complete. Interim results available were furnished for incorporation in the engineering study.

The engineering and the geological portions of the study have provided the data to determine whether the Atchafalaya River, *if left alone,* will capture the Mississippi River.

INTRODUCTION

General

All available engineering information on the changes in the carrying capacity and alignment of the Atchafalaya and Old Rivers has been collected and studied. The geology of the Atchafalaya Basin, together with its probable effect on the river's future regimen, has been used to complement the engineering report. All phases of river hydraulics were thoroughly analyzed. Factual data on the rate and extent of progressive changes in bank lines and sections of Old River and the Atchafalaya River, from its head through Grand and Six Mile Lakes to the Gulf of Mexico below Morgan City, Louisiana, together with rate and amount of deposition in the lake region of the lower Atchafalaya and the leveed portion of the upper Atchafalaya River, were analyzed and are presented in this report and its appendices A, B, and C. The effectiveness of the Wax Lake Outlet in discharging excess waters from the lower Atchafalaya Basin has been considered and included in the study.

Problem

The problem in this study is the distribution of the flow of water (3,000,000 c.f.s.) at the confluence of the Mississippi, Red, Atchafalaya, and Old Rivers, in which the Mississippi and the Red Rivers contribute the discharge from their watersheds; the Atchafalaya River acts as a distributary for the Red and the Mississippi Rivers, and Old River, the connecting link, permits interchange of water from the above basin areas. (See Plate B1, Appendix B, showing the general area at Old River.)

The solution of the problem requires the determination from engineering and geological studies: (a) whether the Atchafalaya River, if left alone, will capture the Mississippi; (b) if so, to determine the length of time this development will take; and (c) what control steps should be taken to prevent such an occurrence and also provide suitable navigation between the Mississippi and Red Rivers.

History

In a very early period the Red River and the Mississippi River had different channels and were not connected as at present in the vicinity of Old River, but some four hundred and fifty years ago the Mississippi River meandered westwardly and caved into Red River at a point which is now about the west side of Turnbull Island. The Mississippi River continued caving westwardly and the Red River flowed into the Mississippi River at the upper side of the bend and an outlet (now called the Atchafalaya River) remained at the lower side of the bend. The rivers continued to flow in this manner until 1831 when Shreve's Cutoff was made (Plate B78, Appendix B) across the narrow neck of the peninsula forming the interior of the horseshoe bend, and left the mouth of Red River and the head of the Atchafalaya River in an oxbow lake with a two-way connection with the Mississippi River.

Prior to 1846, the Atchafalaya River was blocked with raft material (trees, snags, drift, etc.) at its upper end so that comparatively little water passed down its channel and the banks below Simmesport, Louisiana, were never overflowed except from overbank flow and backwater. This raft was some thirty miles in length, and under certain conditions, could be used as a passageway for walking across the river. The State of Louisiana, in 1840, undertook the removal of the raft to make a navigable channel and from the time the channel was cleared, the Atchafalaya River has been steadily enlarging.

After the creation of the Mississippi River Commission in 1879, various plans for the rectification of the Atchafalaya River and the mouth of Red River were proposed. The plan of the Commission in 1884 provided for a series of brush and stone dams in the Atchafalaya River to be built up to just below low water. Two sill dams, Nos. 1 and 3, were built in the Atchafalaya River at Simmesport, Louisiana, in 1888 and 1889, respectively. A sill and dam were also built across that portion of the Mississippi River abandoned by Shreve's Cutoff from the west shore of Turnbull Island westwardly to the mainland and located between the mouth of Red River and the head of the Atchafalaya River. This structure was also called Red River Dam and was abandoned in 1896. Sill Dam No. 1 was enlarged along the upstream side and the Louisiana Railway and Navigation Company bridge was constructed across the river at Simmesport, Louisiana, in 1927-28 on this upstream extension of the sill.

A number of studies and reports relative to the complete closure of Old River, except for a lock for navigation, were made prior to the passage of the Flood Control Act of May 15, 1928. In general, these reports indicated such closure would cause a rise in stage of about 4 feet in the Mississippi River below mouth of Old River. Since the city of New Orleans and the levee boards along the river could not raise their levees to care for such an increase in flood stages, Old River remained open.

Under the 1928 Flood Control Act and amendments, the Atchafalaya River has been improved to carry additional floodwater, and the project, as revised, is based upon a discharge of 650,000 cubic feet per second down this river past Simmesport, Louisiana.

The water elevations for various flood conditions at the junction of the Atchafalaya and Mississippi Rivers are, in general terms, applicable to either stream at this latitude, but the distance from Old River via the Mississippi River to Gulf level at Head of Passes is 302 miles, while the distance from Old River via the Atchafalaya River to Gulf level in Grand Lake (Myette Point) is only 100 miles. This difference in distance to Gulf level with the same head elevations of the water at Old River creates a favorable condition to force water to go down the Atchafalaya River in increasing quantities. The Atchafalaya River has enlarged so that it is now taking its portion of the project flood discharge past Simmesport, Louisiana, at stages less than project heights. Under existing conditions, a project flood would cause discharge in excess of project requirements to flow past Simmesport, Louisiana.

Authority for Report

This report on the Atchafalaya River study is submitted in compliance with directives received from the Chief of Engineers, U. S. Army, as follows:

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON

ENGWD 29 September 1950

SUBJECT: Atchafalaya River Study

TO: The President
Mississippi River Commission
Corps of Engineers
Vicksburg, Mississippi

1. In line with our conversation last week and 1st Ind. to your letter of July 31 on the subject of "Employment of Geologists," it is desired that you expedite and submit your study of the Atchafalaya River.

2. The study should include adequate profiles and actual sections to indicate with factual data the rate and extent of progressive changes in bank lines and sections of Old River and the Atchafalaya River from its head in Old River through Grand and Six Mile Lakes to below Morgan City. In presenting the changes leading up to existing conditions it is pertinent to include information on the rate and amount of deposition in the lake region of the lower Atchafalaya River as well as on changes in the leveed portion of the upper Atchafalaya River.

3. A statement as to the effectiveness of the Wax Lake Outlet in discharging excess waters from the lower Atchafalaya Basin should be included in your study.

/s/ LEWIS A. PICK
Major General
Chief of Engineers

* * * * *

SUBJECT: Employment of Geologists
(Ltr MRC to OCE, 31 July 50)

ENGMR

1st Ind

Office of the Chief of Engineers, Washington, D. C., 29 September 1950

TO: President, Mississippi River Commission, Corps of Engineers, Vicksburg, Mississippi

1. The importance of acquiring all possible information on probable changes in the discharge capacity of the Atchafalaya River is recognized and since the alluvial geology of the Atchafalaya Basin may have an important effect on that river's future regimen, engineering planning for the future should take into account all the ascertainable geological facts.

2. The Corps of Engineers and the Mississippi River Commission have been studying the lower Mississippi River, its tributaries and distributaries for about 100 years. They have collected and have available a tremendous amount of data. The Department has engineering personnel well versed in all phases of river hydraulics, mapping and the design and construction of river control works as well as equipment available for making necessary engineering investigations.

3. The President, Mississippi River Commission, is authorized to employ Dr. H. N. Fisk, under the conditions recommended, to make a report on the geology of the Atchafalaya Basin, with particular reference to the probable future regimen of the Atchafalaya River. The employment of Mr. L. J. Wilbert, Jr., as geological assistant to Dr. Fisk, under the conditions recommended, is also approved.

4. There appears to be no need for employing other outside engineering talent, since the Department has available all the means necessary to give Dr. Fisk whatever additional engineering data and assistance he may need.

/s/ LEWIS A. PICK
Major General
Chief of Engineers

October 1950

MEMORANDUM ON ATCHAFALAYA RIVER STUDY
(Received from Chief of Engineers, U. S. Army)

1. Reference is made to (1) conversation of the Chief of Engineers and the President of the Mississippi River Commission in Washington 23 September 1950; and (2) 1st Ind. dated 29 September on President, M. R. C. letter of 31 July on "Employment of Geologists"; and (3) Chief of Engineers' letter to President M. R. C. dated 29 September on "Atchafalaya River Study."

2. The employment of Dr. H. N. Fisk and an assistant geologist has been authorized in order that your study may take into account *all* of the ascertainable facts about the geology of this river and its basin. It is important, however, to recognize that this study must include sufficient survey records and accurate engineering data to warrant conclusions. As brought out in the discussion we do not wish to continue the practice of alternately increasing and then decreasing the flows through the Atchafalaya River. We should have enough sections and profiles of Old River and the entire length of the Atchafalaya River from its head in Old River to below Morgan City, La. to indicate the rate and extent of change taking place.

3. A vast amount of this information has been compiled over a long period of years and if brought to date with current surveys and records it will indicate what if any progressive changes have taken or are taking place. Moreover it should indicate the relationship between deposition in the lake and swamp region of the Atchafalaya River and alleged enlargements in the leveed portion of that river.

4. Known bank lines of former years should be superimposed on a current plan drawing. Profiles for the entire river should be plotted to the same scale with sections at appropriate points presented in such manner as to be readily compared with former years.

5. It would seem pertinent to relate present findings and conclusions to the findings and opinions expressed in prior reports such as Humphreys and Abbot, Annual Reports of the Mississippi River Commission, the Spillway Board Report of 1927, etc.

6. Finally, it is intended that this study should be thorough in engineering and comprehensive in compiling basic data, supplemented with such geological information as may be obtained at a limited cost in a reasonable length of time. It is not intended that the study should constitute a formal report of the type prepared for submission to Congress and publication as a government document.

7. The Chief of Engineers and his office should be kept informed on the progress of this investigation and study.

Procedure

In order to fulfill the directive of the Chief of Engineers, U. S. Army, the President of the Mississippi River Commission called a conference on 20 October 1950 in which he outlined the procedure and assigned the responsibilities for the preparation of the report. The conferees were General Feringa, President, Mississippi River Commission; Colonel McCarty, Assistant to the President, Mississippi River Commission; Colonel Holle, District Engineer, New Orleans District; R. A. Latimer, Chief Engineering Assistant; C. W. Schweizer, E. J. Williams, and A. L.

Aldridge, Office of the President, Mississippi River Commission; G. H. Hudson and J. C. Baehr, New Orleans District; W. J. Turnbull, Waterways Experiment Station; and Dr. H. N. Fisk, geological consultant.

As an aid in efficient assignment of duties, the preparation of the report was divided into two portions, an engineering study and a geological investigation, both of which were utilized in preparing the final report by the Mississippi River Commission.

The New Orleans District was assigned the duty of making such additional surveys as required and developing the engineering factual data, plates, and compilations needed for preparation of the body of the report, such as superimposing known bank lines on a suitable map, preparing profiles, making cross-section comparisons, taking discharge observations, and securing sediment samples. The New Orleans District work was completed and furnished the Mississippi River Commission about 1 April 1951, and is entitled "Appendix B."

Dr. H. N. Fisk, geological consultant, was assigned the responsibility for the development of the complete geological study within the Atchafalaya Basin. He furnished such geological information, findings or tentative conclusions, drawings and illustrations as were available and pertinent to the engineering study. The geological study could not be entirely completed by the date set for submission of the engineering portion of the report and additional time will be required to make the complete geological study of the Atchafalaya Basin.

Mr. W. J. Turnbull of the Waterways Experiment Station was assigned the responsibility for coordinating and supervising the layout of borings, collection of soil and geological data needed for the study, and coordinating the work of the Waterways Experiment Station and the New Orleans District boring parties. The analysis of the borings and the preparation of necessary illustrations of borings for inclusion in the engineering and geological studies were also assigned to the Waterways Experiment Station. This work, together with such geological findings as were obtainable for use in the engineering study, was completed and furnished the Mississippi River Commission about 1 April 1951 and is entitled "Appendix A."

The "Effect of Engineering Works on the Development of the Atchafalaya River" was assigned to Mr. Williams of the Engineering Division, Office of the President, Mississippi River Commission. This portion of the study was completed about 10 April 1951 and is entitled "Appendix C."

Personnel of the Mississippi River Commission, in cooperation with Dr. Fisk, his assistant, Professor Wilbert, and representatives of the New Orleans District and the Waterways Experiment Station collaborated in the collection and evaluation of all engineering and geological data used in the preparation of the final report.

Mr. Latimer, Chief Engineering Assistant, acted as coordinator of the engineering study, with Mr. Schweizer as assistant, and had the responsibility for the preparation of a draft of the final report for review by the Mississippi River Commission during its May 1951 high-water inspection trip.

A majority of the members of the Mississippi River Commission, accompanied by Colonel Holle, District Engineer, New Orleans District, Mr. F. B. Slichter, Chief of Engineering Division, Office, Chief of Engineers, and Mr. H. V. Darling, Chief Engineering Assistant to Colonel Ernest Graves, Resident Member, Mississippi River Commission, Office, Chief of Engineers, made a two-day inspection of the Atchafalaya River and Basin by boat on 23 and 25 January 1951. An airplane inspection of the basin was also made on 25 January 1951. All available data on the study were shown to all members of the party by Mr. Latimer, who gave a brief outline of the proposed study, progress to that date, and tentative conclusions, based on limited data, after which suggestions as to adequacy of proposed outline, improvement or expansion of the field of investigations were requested.

A majority of the members of the Mississippi River Commission have displayed an active and continuous interest in the study by visiting the Office of the President, Mississippi River Commission, where they inspected, reviewed the data as accumulated, and offered suggestions for improvement of the study.

Suggestions made known by the members of the Mississippi River Commission and the representatives of the Chief of Engineers have been considered and incorporated in the report.

DESCRIPTION OF ATCHAFALAYA RIVER

Chronological History of Its Formation and Improvements

The Atchafalaya River is not, strictly speaking, a river, but is a distributary for waters from the Red, Ouachita, and Mississippi River Basins, with a restricted section near Simmesport, Louisiana, which is now five miles below the head of the stream formed by its junction with Red and Old Rivers.

Alluvial ridges of abandoned Mississippi River meander belts in the vicinity of Old River may be traced for miles from their position of divergence from the ridge along the present Mississippi River course (Plate A1, Appendix A).

A study of these meanders indicates that prior to approximately the tenth century, the Mississippi River drainage followed the Walnut Bayou channel, which differed from the present drainage channel. At this time, the Mississippi River, together with the major discharge of Red River, was flowing eastwardly in the vicinity of Simmesport, Louisiana, and entered the present Mississippi channel near the mouth of Old River. Also, in this period, Yellow Bayou, Moreau Bayou, and the Atchafalaya River (Pelousas Bayou) may have been crevasse channels or small distributaries of the Mississippi River and similar in pattern to the Little Tensas, Big Tensas, and Blind Tensas Bayous now flowing from Upper Grand River into the Atchafalaya Basin.

Shortly after the tenth century, the Mississippi River, while flowing in the Walnut Bayou course, developed a diversion into the Yazoo River drainage system near Vicksburg, Mississippi. The Mississippi River waters followed the Yazoo drainage channel southwardly to near Angola, Louisiana, and in the next century enlarged this course to form the main channel of the Mississippi River, gradually abandoning the older Walnut Bayou course on the west.

From the eleventh century to the eighteenth century, the Mississippi River in the latitude of Old River meandered westwardly across the basin from the bluffs on the east to its position just prior to the development of Shreve's Cutoff. In enlarging a westwardly migrating bend around what is now known as Turnbull Island, it is postulated that in the fifteenth century it caved into the old deteriorated channel of the Walnut Bayou course, now used by Red River, which had carried flow to the Mississippi River through a channel now known as Bayou Lettsworth. The water from the Mississippi River, due to this junction, probably reversed the flow in the old Walnut Bayou channel (now called Bayou des Glaises) from the Mississippi River to a distributary called Pelousas Bayou at Simmesport, Louisiana. This stretch of river above Simmesport, together with the distributary below it, is now known as the Atchafalaya River.

The channel conditions of this locality in the fifteenth century, as derived from aerial photographs and geological investigations, are also confirmed by a map drawn in 1576 in Madrid, Spain, by Monk Ptolemy who, as one of De Soto's expedition, was in this locality about 1542. Conditions as of the seventeenth century are borne out by Broutin's map, 1722, prepared by the French Government in Paris, France. Maps made in 1765, 1800, 1830, 1880, and to date verify the channel changes as of those periods (Plate B78, Appendix B). Maps indicating the channel changes in the Old River area in approximately 100-year intervals from the fifth century to 1950, as reconstructed from aerial photographs and geological investigations, form part of this report (Plates 1-16).

The Mississippi River, after reaching the old Walnut Bend course, continued its meandering westwardly, causing the Red River to flow into it at the upper side of the Mississippi River bend, and an outlet (now the Atchafalaya River) remained as a distributary at the lower side of the bend (Plate B78, Appendix B). The Atchafalaya, as it then existed, was a great drift chute for the Red and Mississippi Rivers and was choked up by a mass of drift known as a "raft" which rose or fell with the changes in water surface elevations.

The river continued to flow under these conditions until 1831 when Shreve's Cutoff was made (Plate B78, Appendix B), artificially, in the Mississippi River across the narrow neck of the peninsula forming the interior of the horseshoe bend. This cutoff left the mouth of Red River and the head of the Atchafalaya River in an oxbow lake with a two-way connection with the Mississippi River. The upper portion of the cutoff bend was called Upper Old River, and the lower part Lower Old River. Due to Shreve's Cutoff, the Atchafalaya River raft ceased to grow.

The first effort toward removing the great obstruction was made in 1839 by citizens who resided on the river. Constant appeals to the state for aid, without success, induced a few citizens of the Atchafalaya, under the direction of Captain Laird, to take the remedy in their own hands, and availing themselves of one of the seasons of greatest drought, they set fire to the raft. The water in 1839 was so low that foot passengers, by means of a plank 15 feet long, could walk across the river. The fire swept over the raft, some twenty miles in extent, destroying thousands of alligators and burning off the immense mass of timber to the water's edge, but it did not remove the raft below the water. The State of Louisiana, in 1840, undertook the removal of the raft, using snagboats, and the raft was cleared to the extent needed for steamboat travel in April 1842. This cleared channel was not permanent, however, as the State Engineer of Louisiana reported in 1847 that the Atchafalaya was filled with raft and floating drift from a point two miles above Pigeon Bayou to within seven miles of its head. These rafts were broken up from year to year and evidently they were all removed before 1855.

After the creation of the Mississippi River Commission in 1879, various plans for rectification of the Atchafalaya, Red, and Mississippi Rivers were proposed. The first authentic survey of the Atchafalaya outlet was made by Major C. W. Howell in 1880-81, and extended from Berwick Bay to the mouth of Red River. Major Amos Stickney reported the improvement was so intimately connected with the Mississippi River that no recommendations could be made until the Mississippi River Commission took action.

Mississippi River Commission proposed plan

The plan of the Commission in 1884 called for a series of brush and stone sill dams placed in the Atchafalaya River, with the upper one just below Bayou des Glaises *and five others downstream at intervals not exceeding one quarter of a mile.* These dams were to be built up to just below low water and permit the passage down the Atchafalaya River of a volume of flow equal to the flood discharge of Red River.

On August 21, 1886, the Mississippi River Commission set up this project and work was commenced on Sill No. 1, which was 500 feet below the mouth of Bayou des Glaises. It was at the general location of the present highway and railroad bridge at Simmesport, Louisiana, and was built up to within six feet of the low-water mark, which permitted river navigation (Plates B82 and B16, Appendix B). Sill Dam No. 1 was completed December 21, 1888.

Sill Dam No. 3 was constructed during the fiscal year 1889 with its upper edge 1,750 feet downstream from the lower edge of Sill Dam No. 1. Work was commenced November 26, 1888, and the structure was completed August 27, 1889 (Plate B16, Appendix B). The other four dams planned in this project by the Commission were not constructed.

The last maintenance on these two dams, by the United States, was performed in 1920. In 1926, the Louisiana Railway and Navigation Company placed additional work near Sill Dam No. 1 in connection with building their bridge across the river in this locality. Maintenance of Sill Dam No. 1 by the Louisiana and Arkansas Railroad ceased after 1934. Sill Dam No. 3 gradually deteriorated, due to caving banks and lack of maintenance, and is no longer effective as a sill dam.

In connection with the over-all project, a sill and dam (Red River Dam) were built across the river from the west shore of Turnbull's Island westwardly to the mainland, and located between the mouth of Red River and the head of the Atchafalaya River. The crest of the dam was to have a suitable elevation above the obstructions in Upper Old River, its object being to force the Red River, when below a certain low stage, to discharge its flow through Upper Old River into the Mississippi River. This structure was completed by November 17, 1891, but due to very low river stages it was necessary to remove a part of the dam for navigation purposes. Minor repairs were made to this dam in 1894. It was reported in bad condition in 1895, and appears to have been abandoned in 1896 (Plate B78, Appendix B).

The connecting navigation channel between the Mississippi River and the Red and Atchafalaya Rivers was at times in Upper Old River and again in Lower Old River. Finally, Upper Old River silted up and a navigation channel was maintained in Lower Old River.

The Louisiana Railway and Navigation Company used the Lower Old River channel for transporting railroad equipment and cargoes from their incline at Naples, Louisiana, on the west bank of Red River, to their incline at Angola, Louisiana, on the east bank of the Mississippi River. With the exception of a few years, maintenance of this channel required annual dredging in the Mississippi River at the mouth of Old River until 1937. Ferry transportation service over this route was discontinued after the combination railroad and highway bridge was erected at Simmesport, Louisiana, in 1927-28. Railroad traffic was then routed over the bridge, with rail connections to an incline on the west bank of the Mississippi River just below the mouth of Old River (Plate B79, Appendix B). Prior to the construction of this incline, the main channel of the Mississippi River at Red River Landing was on the west side of the river part of the time, and on the east side of the river at other times. This condition created a middle sand bar in the Mississippi River. The incline acted in the nature of a permeable pile dike and created a stabilizing effect that held the main channel of the Mississippi River at all times on the west side of the river, causing the east channel to fill up. The east channel is now covered by a high sand bar extending out from the bank to approximately the middle of the original main channel. The current then attacked the west bank in Old River continually, and, in 1944, Carr Point Cutoff was made across a narrow neck of land between the Mississippi River and Old River. In 1946, a sand dam was built in the Old River channel abandoned by the cutoff, to alleviate the very active bank caving in front of the main west bank levee and to prevent the Mississippi River from adopting it as part of the channel. In 1949 and 1950, revetment was placed in the Mississippi River above and below the mouth of Old River to prevent further bank erosion at this locality (Plate B15, Appendix B).

The only bridge across Old River, built by the Texas and Pacific Railroad in 1902, is no longer in use. In the survey of Old River in 1910, it was found that a revetment had been placed to protect the bridge piers from erosion. This revetment restricted low-water flow and enlargement of the section at this point, and at the Mississippi River Commission's request the obstruction was removed by the railroad company in 1912. The ownership of the bridge was transferred to the Louisiana State Highway Commission when the railroad discontinued service on this line after the 1927 flood. Some time after the Carr Point Cutoff was made in 1944, the north span of the bridge fell into Old River for lack of a supporting foundation. This portion of the steel bridge is now in Old River and is a hazard to navigation passing on the north side of the stream. The bridge is no longer used for any purpose, and the swing span of the bridge is left open on the pivot pier and permits boats to use the navigation channel (Plates B85 and B15, Appendix B).

Under the original 1928 project plan (Plate B77, Appendix B), a flow of 1,500,000 cubic feet per second was to be diverted through the Atchafalaya Basin to the Gulf of Mexico near Morgan City, Louisiana, 500,000 c.f.s. to pass down the Atchafalaya River proper, and the remainder to go down the east and west floodways. This plan was later revised to divert 600,000 c.f.s. through Morganza Floodway, 250,000 c.f.s. through the west floodway, and 650,000 c.f.s. down the Atchafalaya River proper.

The Louisiana and Arkansas Railroad bridge at Simmesport, Louisiana, was reconstructed under the terms of the present flood control project to provide a suitable and safe crossing for an ultimate river discharge of 750,000 c.f.s. by adding additional spans to the west end of the bridge and enlarging the river channel under these new spans by dredging. This work removed Sill Dam No. 1 from Pier No. 2 westwardly (Plates B80 and B82, Appendix B). The New Orleans, Texas and Mexico Railroad bridge (Mo. Pac. RR) at Krotz Springs, Louisiana, has been enlarged, by additional spans and dredging on the west bank, to carry additional flow. It is planned to raise the entire bridge to provide clearance for highest project stages. The highway bridge at Krotz Springs, Louisiana, has not been changed. The Texas and Pacific Railroad bridge at Melville, Louisiana, is now being enlarged by additional spans on the east bank. The Southern Pacific Railroad bridge (ML&T RR) at Atchafalaya, Louisiana, fell into the river during the 1927 flood, after which the railroad east of the Atchafalaya River was abandoned. The Southern Pacific Railroad bridge (T&NO RR) from Morgan City west, across Berwick Bay, has been raised recently to care for additional flood heights (Plates B79, B80, and B81, Appendix B).

In connection with corrective dredging operations and improving the discharge capacity of the Atchafalaya River, dredging work under the flood control project (Plate B83, Appendix B) was performed during 1932 to 1940 from Barbre Landing (0) to Grand Lake (99 miles below the head). The cross section of the river at the Louisiana and Arkansas Railway bridge (4.9) was enlarged, the channel on the right side of the river from Mile 3.0 to Mile 4.0 just above the railroad bridge at Simmesport, Louisiana, was deepened, and the channel at various localities between Simmesport (5) and Melville, Louisiana (30), was dredged to 40 feet below mean Gulf level over a 250-foot bottom width. Between Melville, Louisiana, and Grand Lake (Myette Point) dredging was performed to develop channel capacity; the section at the N.O.T. & M.R.R. (Mo. Pac. RR) bridge at Krotz Springs, Louisiana, was enlarged; and an entirely new river channel with a depth of 30 feet over a 250-foot bottom width was created from Whiskey Bay to Grand Lake via Whiskey Bay Pilot Channel (54-64), Blind Tensas (68), Lake Mongoulois (72), Bayou Chene Cut (74), Tarleton Bayou (76), Big Bayou Chene (78), Lake Chicot (79), Chicot Pass (85), and Myette Point Cut (95).

The 1880 report of the Mississippi River Commission states that both banks of the Atchafalaya River at Simmesport, Louisiana, were caving; that three successive levees had been built on both sides of the river, and in some places the fourth levee was at the top of the bank and in danger of falling in.

As of 1881, the levees on the Atchafalaya River extended 13 miles below the head of the stream on the east bank and 26 miles below the head on the west bank. By 1907 they were built to Mile 43 and Mile 42, east and west bank respectively; in 1927 their lower ends were at Mile 55 and Mile 43, and at present the continuous levee ends at Mile 55 on the east bank and at Mile 67 (approximately) on the west bank (Table 29, Plate B98, Appendix B).

The building of levees expedited the changes that took place in cross section and alignment of the stream. A detailed discussion of the levees, with factual data, is presented in the appendices of this report. Discussions on grade and flow lines, stage relations, discharge and sediment movement, surveys, and geological investigations are also furnished as data pertinent to the problem under appropriate headings in Appendices A, B, and C.

Bibliography

All data available in early reports, together with recent surveys, reports, and geological publications, were used in the preparation of this report to obtain all possible historical engineering and geological information on the capacity and alignment of the Atchafalaya and Old Rivers, together with the probable effect on the future regimen of these rivers. Extracts from various reports also form part of this report.

A list of the reports and publications reviewed, together with maps pertaining thereto, is as follows:

~~De Soto's expedition, 1542, written history and maps;~~

Broutin's map of Old River, by the French Government, 1722;

Louisiana State Board of Engineers, early and recent reports and surveys;

Maps of Lieut. Ross (1765); Capt. Philip Pitman (1768); Gen. Victor Callot (1796); and Capt. H. Young (1820);

Maps of the General Land Office, showing meander lines of streams when U. S. was sectionized in Louisiana (1809 to 1845);

William Darby's geographical description of Louisiana, 1816;

Report on Shreve's Cutoff, 1831;

Charles Ellet's report on the Mississippi River, 1850, Congressional Committee Document;

Humphreys and Abbot, "Report Upon the Physics and Hydraulics of the Mississippi River," 1861 and later editions (with maps);

Annual reports of the Chief of Engineers, U. S. Army, 1871 to date;

Board of Engineers report on levees and reclamation of the Alluvial Valley, 1874-75;

Early surveys of the Atchafalaya River by Major C. W. Howell, 1874-1881;

Annual reports of the Mississippi River Commission, 1879 to date (early MRC reports also contained extracts and writing of conditions many years prior to creation of the Commission);

Surveys and reports on Atchafalaya and Old Rivers made by the Commission in 1882-83; 1904-05; 1916-17; 1927; 1932; 1937; 1945; and 1950;

Report on "Separation of Red and Atchafalaya Rivers from the Mississippi River," H. D. 841, 63d Cong., 2d Session, 1914 (an exhaustive report showing conditions as surveyed in 1911);

Reports pursuant to Act Jan. 21, 1927, and H. D. No. 308, 69th Congress, 1st Session;

Report on Atchafalaya and related basins, 1919, H. D. 288, 66th Cong., 1st Session (showing conditions as surveyed 1916-17);

Examination and survey provided by Act of March 3, 1921, of Atchafalaya, Black, and Red Rivers for protection of these basins from floodwaters of the Mississippi River, July 1926;

Spillway Board report of 1927, H. D. 95, 70th Cong., 1st Session;

Flood Control Documents, May 15, 1928, Act to date, including the Commission's report on a flood control plan;

Report on "Control of Floods in the Alluvial Valley of the Lower Mississippi River in 1931," H. D. 798, 71st Cong., 3d Session (in three large volumes, including maps);

Red River Backwater report;

Red River Closure report;

Reports of prominent engineers and officers published in Transactions of American Society of Civil Engineers;

Articles published in Civil Engineering magazines; Louisiana Department of Conservation; Geological Society of America; American Association of Petroleum Geologists;

Congressional records as published;

Report on "The Improvement of the Lower Mississippi River for Flood Control and Navigation" (an exhaustive report on the Mississippi River in three volumes, with maps) published by the Commission, May 1932, together with an additional report on dredging performed under the Flood Control Act of 1928;

Report on "Geological Investigation of the Alluvial Valley of the Lower Mississippi River" prepared by Harold N. Fisk, Prof. of Geology, Louisiana State University, December 1944 (an exhaustive study, with maps, conducted for and published by the Mississippi River Commission);

Report on "Geology of the Lower Red River" prepared by the Geology Branch of the Waterways Experiment Station and published by the Waterways Experiment Station, September 1950;

Unpublished data contained in letters and memoranda in the files of the Mississippi River Commission and Lower Mississippi Valley Division. (See extracts compiled from various reports.)

Data Pertinent to the Problem

The most pertinent part of the problem in this study is *WATER*. Where it comes from and where it goes. Water comes primarily from precipitation and is an act of nature and cannot as yet be controlled by man. Where it goes can be regulated by engineering structures designed after a complete study of all conditions pertaining to the problem has been made.

An average alluvial stream has a given drainage area that controls the water or discharge carried by that river, but the Atchafalaya River is a distributary with a variable drainage area which materially influences its normal discharge or carrying capacity.

The Red-Ouachita Basin, covering approximately 90,000 square miles, might be considered the normal area from which water would enter the Atchafalaya River at its head, but the connection between the Atchafalaya River and the Mississippi River at Old River, 302 miles above the Passes, permits water from the remainder of the Mississippi River Basin of 1,150,000 square miles to enter the Atchafalaya River through this connection and surcharge the carrying capacity of this stream (Plate B1, Appendix B). A normal annual precipitation over the entire Mississippi drainage basin varies from 20.7 inches on the Missouri River watershed to 48.8 inches in the Lower Mississippi River Valley, while rainfall over the Red and Ouachita Rivers Basin averages 38.3 inches. The runoff from the rainfall creates the discharge of the river, which is measured at selected stations with reference to a gage or some datum plane.

Discharge quantities

From records available for Vicksburg, Mississippi, discharge station on the Mississippi River, it appears that an average discharge of 18,776,772,000,000 cu. ft. of water, weighing 586,774,125,000 tons, was carried down the river *annually* over the past period of 133 years. This represents an average discharge of 595,000 cu. ft. of water at this station for every second of time in the entire 133 years. With a base area of one acre (43,560 sq. ft.), this average volume of water *per year*, if stood on end, would extend 431,055,400 ft. or 81,640 miles in height.

The year 1950 had an unusually large annual discharge of 27,360,439,200,000 cu. ft. which passed Vicksburg with an average discharge of 867,000 cu. ft. for every second in time. This discharge was carried to the Gulf of Mexico without any unusual incidents, although it was only slightly less than the 1927 annual flow.

From records at Red River Landing, Louisiana (below mouth of Old River), and covering the period 1912 to 1950, an average annual discharge of 16,282,080,000,000 cu. ft. of water passed this station on its way to the Gulf of Mexico. This represents an average discharge of 515,950 cu. ft. of water for each second during the period.

The storage capacity of the Lower Mississippi River, Cairo, Illinois (966), to the Head of Passes (0), using the area between bankfull and low-water stages, has been computed as 706,153,922,000 cu. ft. In a large flood year (1927 confined) over one million millions of tons of water flowed down the Lower Mississippi River Basin ~~during the 12-month period. Of this total discharge, the Upper Mississippi River~~ contributed approximately 13 percent; the Missouri, 13 percent; the Ohio (exclusive of the Tennessee and Cumberland), 25 percent; the Tennessee and Cumberland, 11 percent; the White, 8 percent; the Arkansas, 9 percent; the Red, 4 percent; and various other smaller streams contributed the remaining 17 percent. All of this 1927 flow passed into the Gulf of Mexico, 78 percent going down the Mississippi River towards New Orleans, Louisiana, and 22 percent going down the Atchafalaya River toward Morgan City, Louisiana. At the present time, 70 percent of the total flow at the latitude of Old River goes down the Mississippi River and 30 percent goes down the Atchafalaya River (Table 33, Appendix B, and Plate 17, basic report).

These enormous flows erode the riverbanks, and for the period 1931 to 1941 approximately 800,000,000 cu. yd. of bank material caved into the Mississippi River between Cairo, Illinois (966), and Old River (301), a distance of 665 miles.

Suspended sediment carried by the Mississippi River was measured at Baton Rouge, Louisiana (Plate B101, Appendix B), for the period 1 October 1949 to 30 September 1950, and for a discharge of 246,222,000 day-second-feet, 555,964,000 tons of sediment were carried past this station, with an average of 840 parts per million by weight. Sediment observations were also taken at Red River Landing in November 1950 and January 1951 (Tables 13 and 18, Appendix B).

At Simmesport, Louisiana (5), on the Atchafalaya River, records covering the period 1912 to 1950 show that an average annual discharge of 4,696,012,800,000 cu. ft. of water passed this station to the Gulf at Morgan City, Louisiana. This represents an average discharge of 148,808 cu. ft. of water for each second during the 365 days of the year.

The Atchafalaya River at Simmesport, Louisiana, derives its discharge from a vast watershed, and records for the period 1928 to 1949 show that the average yearly discharges, in percentage of flow, were from the following areas: Ouachita Basin, 11.6 percent; Red River Basin, 22.6 percent; Mississippi River Basin through Old River, 57.0 percent; and local miscellaneous flow, 8.8 percent. Average yearly peak discharges for the same period in percentage of flow were: Ouachita Basin, 11.8 percent; Red River Basin, 26.7 percent; and Mississippi River Basin through Old River, 61.5 percent. (Table 32 and Plate B86, Appendix B.)

Discharges are plotted to gage heights at the selected gaging station (Plate B40, Appendix B), and this method of showing discharges is used to compare cubic feet per second of flow without regard to the conditions under which the observations were taken. The discharges, in cubic feet per second, are directly comparable by gage heights solely when all the conditions of flow are identical, and this rarely happens. A great many conditions affect discharge in an alluvial stream that carries up to 2,500,000 c.f.s. and is subjected to man-made structures in addition to those imposed by nature.

A few of the many conditions affecting stream flow are:

A migrating river flowing in an alluvial basin, with resulting caving banks and sand waves;

Alignment and cross section changing continuously, affecting river stages and surface slopes;

Dredging to maintain a navigable channel of project depth and width over sand bars;

Crevasses that divert flood flows from the main channel;

Levee building which restricts overbank flows and increases flood heights for a given discharge;

Bank stabilization by revetments and dikes constructed in various ways and from selected materials;

Floodways and spillways built to provide a passageway for floodwaters through constricted reaches, or to divert floodwaters away from the main channel of the stream;

Reservoirs designed to regulate flows to reduce flood heights and also generate power or provide irrigation facilities;

Drainage improvements and flood gates to provide protection of backwater basins and drain water off of low areas; and

Cutoffs which shorten the river, increase surface slopes and the carrying capacity of the stream during the period that the shortening is effective.

Aside from the natural and man-made conditions under which the water must flow, it is estimated that under the project flood 3,000,000 c.f.s. will reach the latitude of Old River and must be disposed of without material injury to the adjoining territory (Plate B77, Appendix B).

Surveys, hydrographic

In order to evaluate the effects of this flow and also determine the distribution of this water down the Mississippi River and the Atchafalaya River from earliest records to date, an over-all survey was made in 1950 of the Mississippi River adjacent to mouth of Old River; all of Old River; Red River from Acme, Louisiana, to its mouth; and the Atchafalaya River Basin from the head of the river to the Gulf near Morgan City, Louisiana, including Wax Lake Outlet, to ascertain factual data and present it in this report.

The New Orleans District made the necessary surveys, secured hydraulic and sediment data, and reported on flood control improvements, all of which are presented in a report, with maps and plates, entitled "Appendix B."

The Waterways Experiment Station made borings and collected the soil and geological data, and Dr. H. N. Fisk, Consultant, submitted an interim report on the geology of the Atchafalaya Basin, all of which are presented in the Interim Geologic Report, including maps and plates, and entitled "Appendix A."

The effect of engineering works on the development of the Atchafalaya River was prepared by personnel of the Mississippi River Commission, and is entitled "Appendix C."

Analysis of the various surveys indicates that the Mississippi River mileage from Cairo, Illinois, to the Head of Passes near the Gulf was 1,068 miles in the year 1765; 1,110 miles in 1820; 1,060 miles in 1882; 1,070 in 1916; 1,073 in 1929; 1,001 in 1940; 966 in 1942; and 971 miles in 1950, although the river was shortened 163 miles from 1929 to 1950, of which 152 miles of shortening were due to actual cutoffs and 11 miles due to natural river chutes.

Below Old River, the Mississippi River mileage has been quite stable, being practically 300 miles in length from Old River to the Head of Passes since 1916. Also, the distance from the head of the Atchafalaya River to the Gulf of Mexico via Grand Lake has remained practically the same since 1916. The 1950 distance on the Mississippi River shows 315.3 miles from Old River to the mouth of South Pass and 332 miles to the mouth of Southwest Pass (Gulf of Mexico), while the distance from the mouth of Old River to the Gulf of Mexico via the Atchafalaya River is only 141.5 miles, of which 6.1 miles is along Old River from the Mississippi River to the head of the Atchafalaya River. The water route to Gulf level is 173.8 miles shorter down the Atchafalaya River via Morgan City, Louisiana, than down the Mississippi River via New Orleans, Louisiana, which tends to create steeper slopes and higher velocities through the shorter route.

Cross-sectional areas measured from the 1950 hydrographic survey on the Mississippi River from 16 miles above to 25 miles below the mouth of Old River (302 A.H.P.) show an average bankfull area of 212,000 sq. ft. in the Mississippi River above Old River and an area of 180,000 sq. ft. below that point. A cross-section comparison (Table 41 and Plates B95 and B96, Appendix B) covers the period 1882 to date and shows a tendency toward a decreasing cross-sectional area below Old River.

The maximum stage on Red River Landing gage (zero, 3.49 ft. m.s.l.), 57.45 ft., occurred on 14-17 May 1927 (Table 6, Appendix B), and the lowest stage, -0.6 ft., occurred on 14 November 1895. The maximum discharge was computed for the 1927 confined flood as 1,779,000 c.f.s. for a stage of 61.5 ft. The actual maximum measured discharge was 1,516,000 c.f.s. on 16 April 1945 for a stage of 55.7 ft. A measurement made on 31 March 1882 shows a discharge of 1,595,000 c.f.s. at a stage of 48.3 ft., but this was affected by a large flow through the Morganza Crevasse which was only a few miles below the discharge range. The minimum measured discharge at Red River Landing was 75,000 c.f.s. in 1939 (Table 5, Appendix B).

In Old River, the discharge is influenced by the elevation of the water in the Mississippi River at Red River Landing (mouth of Old River) and the elevation of water at the junction of the Red, Atchafalaya, and Old Rivers at Barbre Landing, Louisiana, 6.1 miles from the Mississippi River. In the early period, the flow was to and from the Mississippi River, depending on whether the stage at Barbre Landing was higher or lower than Red River Landing stage. In 1892, flow in Old River was toward the Mississippi for 208 days of the 365. From 1916 to date, the number of days the flow was toward the Mississippi has been gradually decreasing and, during the last nine years, the flow, with the exception of nine days, was from the Mississippi River to the Atchafalaya River (see Table 36, Appendix B).

The average bankfull area in Old River, referred to 48 ft. m.s.l., in 1894 was 28,000 sq. ft., with a width of 793 ft., mean depth of 35.3 ft., and maximum depth of 56.0 ft., and relatively little change occurred in these dimensions prior to 1908. After 1908 the areas increased to an average of 36,300 sq. ft. in 1922. By 1937, the average area had increased to 50,830 sq. ft., and in 1950, the average area was 61,040 sq. ft. with a corresponding width of 1,195 ft., mean depth of 51.0 ft., and a maximum depth of 85.7 ft. The comparison of average areas through Old River shows enlargement at an increasing rate since 1908, with an over-all increase equivalent to 118 percent of the area available in 1894 (see Table 44, Appendix B).

Using the combined flow of Mississippi River and Old River, the annual percentage of flow through Old River at Torras, Louisiana, for the period 1928 to date varies from 6.9 percent in 1931 to 24.0 percent in 1945. The average annual discharge for this 23-year period was 485,500 c.f.s. at Red River Landing, Louisiana, on the Mississippi River, and 90,100 c.f.s. at Torras, Louisiana, on Old River. In 1950, the average annual discharge was 696,000 c.f.s. at Red River Landing, and 194,700 c.f.s. at Torras. The percentage of flow from the Mississippi River through Old River has increased from 17.0 percent in 1946 to 21.9 percent in 1950. This flow forms a part of the total flow passing the latitude of Old River, which was 30 percent down the Atchafalaya River and 70 percent down the Mississippi River in 1950 (Table 35, Appendix B). This division of flow is essentially constant through all stages.

Suspended sediment carried by Old River was measured on 13 November 1950 and for a discharge of 63,400 c.f.s., with an average of 477 p.p.m., 81,700 tons of material per day passed this station toward the Atchafalaya River. An observation made 20 November 1950, with an average of 915 p.p.m., showed 271,800 tons, and discharge of 110,000 c.f.s.; an observation made 2 January 1951, with an average of

560 p.p.m., showed 175,400 tons per day and discharge of 116,000 c.f.s.; and an observation made 29 January 1951, with an average of 1,039 p.p.m., showed 698,500 tons per day and discharge of 249,000 c.f.s. (Tables 13 and 18, Appendix B).

The maximum stage for the period of record on the Torras, Louisiana, gage (zero, 1.11 ft. m.s.l.) was 60.5 ft. on 15 May 1927 (Table 6, Appendix B). The lowest stage, 2.2 ft., occurred on 4 November 1939. The maximum discharge of record from the Mississippi River toward the Atchafalaya River was 514,000 c.f.s. in 1937, and the maximum flow of record toward the Mississippi River was 310,000 c.f.s. in 1912. The minimum discharge is zero when the water at Barbre Landing and Red River Landing are at the same elevation regardless of river stage.

Comparison of bank lines

The over-all surveys made for this study in 1950 were mapped on a 1:20,000 scale to show changes in bank lines, river mileage, levee locations, comparison of cross sections at suitable intervals along the streams, and have profiles showing top of bank, crown of levee, approved levee grades, water surface slopes for discharge during 1937, 1945, and 1950, approved mean low water 1936, ranges and reaches used in cross-section comparisons, dredged locations, thalweg depths, all referred to mean sea level for elevations and to North American datum for geodetic positions, together with reference to all gages, localities, and improvements. These data are presented on Plates B7 to B93, Appendix B.

Cross sections of the streams from early surveys showed restricted areas were located in Old River at the abandoned Texas and Pacific Railroad bridge near Torras, Louisiana, and in the Atchafalaya River at Sill Dams Nos. 1 and 3, built by the United States at Simmesport, Louisiana (5), and just below Latenache Bayou (28) where a portion of an old raft was not entirely removed (Plates B15, B16, and B18, Appendix B).

Surveys made in 1950 show that the section in Old River at the abandoned Texas and Pacific Railroad bridge is enlarging (Plate B85, Appendix B) and has increased from 29,280 sq. ft. at bankfull stage in 1903 to 67,020 sq. ft. in 1951 (Table 31, Appendix B); that the sill dams in the Atchafalaya River near Simmesport, Louisiana, have deteriorated and the cross-sectional area has increased at Sill Dam No. 1 from 44,480 sq. ft. at bankfull stage in 1888 to 87,450 sq. ft. in 1950 (Table 30 and Plate B82, Appendix B); that the cross-sectional area at Sill Dam No. 3 has increased from 42,730 sq. ft. at bankfull stage in 1904 to 73,400 sq. ft. in 1949 (Plate B16, Appendix B); and the cross-sectional area at Mile 28 (Range 311, Plate B18, Appendix B) is increasing as the river has apparently eroded through an old log raft as indicated in the section developed by the 1950 survey. Comparison of the Atchafalaya River cross-sectional areas, bankfull and low water, by reaches from the head to Whiskey Bay Pilot Channel (54.3) shows a steady over-all increase in areas from the early periods of 1880 and 1904 to the 1950 survey (Table 45 and Plates B98 and B99, Appendix B). From the head of Whiskey Bay channel to Myette Point in Grand Lake, a new main channel has been developed for the Atchafalaya River by dredging where necessary. This route provides a more efficient channel for the discharge of floodwater through this reach, but the necessary channel erosion to carry the project flood safely between the Atchafalaya Basin levees in the lake area has not occurred. If the project discharge is to be carried through this reach without increase in project flow line, it will probably be necessary to provide additional channel capacity by improvement dredging. Plate B83, Appendix B, shows the locations in the basin where dredging was performed, and a summary for the period 1932 to 1948 shows a total of 127,050,000 cu. yd. of material moved to date.

A thalweg profile (Plate B38, Appendix B) shows depths from 60 ft. to 165 ft. below the top of bank in the Atchafalaya River from its head to Whiskey Bay Pilot

Channel, but Grand Lake between this deep water and the Gulf shows a thalweg depth of only 8 ft. This stretch of shallow depths extends from Mile 90 through Grand and Six Mile Lakes and is about 22 miles in length with an average depth of approximately 12 ft. Sediment carried down the Atchafalaya is also being deposited below the ends of the river levees, and for the period 1932 to 1950 a very substantial fill has taken place as shown on Plates B55 to B73, Appendix B. The rate of deposits in the basin from suspended sediment is shown on Plate B100, Appendix B, and ranges from about 30,000,000 cu. yd. per annum in 1930 to about 80,000,000 cu. yd. per annum in 1950. The depth of the fill over portions of the basin below the end of the river levees ranges from 3 ft. to 20 ft. for the period 1932 to 1950, as shown on Plate B74, Appendix B. The accretions in Grand Lake and Six Mile Lake, as determined from surveys and aerial photographs, are shown on Plate B75, Appendix B, for the period 1916 to date. The accretions advanced from Mile 84 to Mile 90 during the period 1916 to 1930; from Mile 90 to Mile 96 for the period 1930 to 1944; and from Mile 96 to Mile 100 during 1944 to 1950. As the area below Mile 100 has already been partially filled by sediment, the rate of accretion advance per year should be accelerated in the remaining 13 miles of the lakes to the head of Stouts Pass. Analysis of the suspended material carried in the Atchafalaya River, and of the material taken off the bed of the stream, is shown in Tables 15-16 and 20-22, Appendix B. Samples of material secured at Wax Lake Outlet were also analyzed and are shown in Table 17, Appendix B.

Analyses of suspended sediment samples from the Mississippi River at Tarberts and Red River Landing, from Old River at Torras, Louisiana, and from the Red River at Alexandria and Acme, Louisiana, are shown in Tables 10 to 14, Appendix B. Borings were also taken to determine the type of material forming the Atchafalaya Basin, and the scope of the geological investigation is presented in Part I of Appendix A (Interim Geologic Report). Materials composing the bed and banks of the Atchafalaya River are grouped into two broad categories: (a) a predominant sandy substratum, which the Atchafalaya River has cut into over a large portion of its length, and (b) a relatively fine-grained topstratum, both of which are discussed in detail in Part IV of Appendix A. Plates accompanying this appendix also show the location, classification, and depth of the various materials.

In connection with the geology and mapping program, aerial photographs have been taken over the Atchafalaya River and adjacent areas. The coverage for the period 1930 to 1950, inclusive, is shown on Plate B39, Appendix B. Mosaics of the basin were not prepared from these photographs due to the limited time available for assembling and submitting the vast amount of data included in this study. Should accurate mosaics be required, they can be prepared from aerial photographs now available for assembling to a suitable scale.

FACTORS PERTINENT TO THE PROBLEM, INCLUDING THE MISSISSIPPI RIVER AND ADJACENT AREAS

General

Under the flood control project, levees have been constructed along the Mississippi River, Old River, Red River backwater, and down the Atchafalaya Basin, including Wax Lake area, with the view of containing the project flood. East and west guide levees have been built in the basin, and project grades established for these structures. Flow lines showing the hydraulic characteristics of the 1937, 1945, and 1950 floods for discharges of 460,000 c.f.s., 640,000 c.f.s., and 630,000 c.f.s., together with status of the leveed heights, respectively, are shown on Plate B37, Appendix B, as profiles referred to mean sea level. The distribution of flow of these floods below the lower ends of the Atchafalaya River levees is shown with the discharge noted at channel sections and also in 20,000 c.f.s. intervals, all referred to mean sea level, and the water surface elevations for these floods are indicated at one-foot intervals (Plates B51, B52, and B53, Appendix B).

The building of levees along the Mississippi River and tributaries has confined the flow of these streams so that in recent years no major crevasses have occurred in flood periods. This condition has created more discharge for a given period at the latitude of Old River. Special outlet structures have been built or are under construction at Morganza, Bonnet Carre, and Wax Lake, Louisiana, to care for this additional discharge. Bonnet Carre and Wax Lake structures have operated according to the project plans, and the necessity for using the West Atchafalaya Floodway has not occurred.

In order to show the division of flow in the vicinity of Old River, mean annual discharges were computed for Red River Landing, Louisiana, representing Mississippi River flow, and similar data computed for Simmesport, Louisiana, showing Atchafalaya River flow (Table 33, Appendix B). To present the information in graphical form, the discharges of these two stations were added together to secure the total flow at the latitude of Old River, and the portion of this total flow passing Simmesport was determined on a percent basis. Plate 17 shows the rate of increase of flow down the Atchafalaya River for the period from 1910 to 1950 and the possible increase from 1950 to 1960. Percent of increase in five-year periods from 1915 to 1960 is also shown. From 1882 to 1910, the flow down the Atchafalaya River increased to 17.2 percent of the total flow; in 1950 it was 30.0 percent; and in 1960, by extrapolation of the curve, it will be about 40.0 percent.

Old River flow

Old River is the distributary which controls diversion into the Atchafalaya River. In order to obtain an indication of the distributary flow and its effects on the controlling section in the main stream channel, graphs were prepared showing comparison of flow through the chute of Island No. 8, with the area of the main Mississippi River channel 10,000 ft. below the head of the chute. A similar graph was prepared for comparison of flow through Brandywine Chute with an area of the main channel 5,000 ft. below the head of the chute (Plates 18 and 19). Excellent survey and discharge data were available for these two locations for about a 10-year period. The main channel area at chute of Island No. 8 showed a tendency to deteriorate when the distributary flow reached 30 percent of the total flow, and after 40 percent of the flow, the main channel deteriorated rapidly. At Brandywine, the main channel area showed deterioration at 20 percent and deteriorated rapidly after 30 percent of the total flow passed through the chute.

Using the same principle, with the view of ascertaining whether the Mississippi River channel below Old River was deteriorating, a fairly straight reach was selected in an area or crossing in the river where change in flow conditions would normally cause sediment to deposit and create a deterioration in the channel. Cross-section areas of the main Mississippi River were plotted at a point about 6 miles below Old River at Miles 296.3 to 295.0, 296.3 to 292.5, and 293.8 to 292.5 (A.H.P.) for bankfull stage, using 1881 to 1950 survey data. These sections have deteriorated from an average area of 184,000 sq. ft. in 1920 to 168,000 sq. ft. in 1949, while the flow into Old River increased from about 7 percent of the total flow to 23 percent for the same periods. This reduction in cross section occurred notwithstanding this stretch of river has been dredged for navigation purposes and there has been no appreciable reduction in the discharge for a given gage height and river/stage condition at Red River Landing discharge range (Plate B89, Appendix B). Cross sections at the discharge range at Red River Landing from 1882 to 1950 show a deterioration in the 1950 cross section when compared with previous years (Plate B90, Appendix B).

The Atchafalaya River is now engaged in pushing an efficient channel to the Gulf and the process involves, first, the deposition of a sedimentary floodplain and, then, cutting a channel across it. The trend to steeper slopes is reversed as the efficiency of the new channel increases, and will eventually result in less slope being required. The Mississippi River has attained a flow and slope condition of this character for its present discharge and, if the Atchafalaya River becomes the main distributary, a water surface slope comparable to the Mississippi River from the Gulf to College Point, Louisiana, would be effective for a similar distance from the Gulf up the Atchafalaya River. This condition would create a water surface elevation at Simmesport, Louisiana, some 30 ft. lower than the present high-water readings at this locality, and part of this lowering, under conditions stated, would be transferred upstream through Old River into the Mississippi River.

Tide gage records

A tide gage was established at Eugene Island in 1939 to ascertain the effect of flood flow conditions just beyond the mouth of the Atchafalaya River. Due to the natural barrier formed by reefs across the mouth of Atchafalaya Bay, abnormally high stages frequently result from the discharge of Atchafalaya River floodwaters. Stages in excess of 3.0 ft. m.s.l. have developed from this cause twelve times since the gage was established, the highest stage being 4.7 ft. m.s.l. in April 1945. Stages due to storms have been above 3.0 ft. m.s.l. on ten occasions during the same period, the highest stage being 4.0 ft. m.s.l. in December 1947. In general, the range between high and low tides is 0.5 foot less during the high-water period than during the low-water period. An examination of the charts of the recording gage at Krotz Springs, Louisiana, on the Atchafalaya River, discloses that only a trace of tidal effect is felt at this latitude during extremely low flows (Table 23, Appendix B).

Salinity near Gulf

A study of salinity records from all stations in the lower Atchafalaya Basin and adjacent coastal areas shows that with the exception of Morgan City and Oyster Bayou stations the normal salinity, reported in parts per million of chloride radical, varies from approximately 25 p.p.m. to 100 p.p.m., with higher values occurring during the low-water season. Sharp increases from the normal occur at Morgan City, Wax Lake Outlet, Black Bayou Settlement, Shell Island Pass, and Four League Bay stations, where the salinity ranges from normal to a few thousand parts per million and thence back to normal again within a few days. The more extreme rises occur nearest the Gulf at Eugene Island and Oyster Bayou, with average high points approximately 12,000 p.p.m. and low points approximating 150 p.p.m. (Plate B76, Appendix B).

Navigation and Dredging

Atchafalaya River navigation—existing project

The existing navigation project on the Atchafalaya River is on the lower Atchafalaya River between Morgan City, Louisiana, and the Gulf of Mexico. The limits of ~~this project are shown on Plate B29, Appendix B~~, and provide for a navigation channel 20 ft. deep and 200 ft. wide, extending from the 20-ft. contour below mean low Gulf level in the Atchafalaya to the same contour in the Gulf of Mexico. Between the head of this project at Morgan City, Louisiana, and the head of the Atchafalaya River at Simmesport, Louisiana, there is no navigation project. However, in response to a Congressional Resolution, a review of reports was recently completed by the District Engineer, New Orleans, and submitted to the Chief of Engineers. This report was favorable to the adoption of a 12-ft. by 125-ft. channel from Morgan City, Louisiana, to the Mississippi River via Old River, Louisiana. On Old River, the connecting channel from the head of the Atchafalaya River to the Mississippi River, the existing project, adopted by the July 13, 1892 Act, provides for the maintenance of a 9-ft. by 100-ft. channel and is a section of the project "Red River Below Fulton, Arkansas."

In the section of the Atchafalaya River from Simmesport, Louisiana, to Morgan City, vessel drafts are restricted to the controlling depths in Six Mile and Grand Lakes. During the annual low-water cycle on the Mississippi, Red, and Ouachita Rivers that normally occurs between July and December, controlling depths in these shallow lakes may be as little as 5 ft. During the remaining part of the year when the high-water cycle prevails on the Mississippi River, there is a substantial increase in the controlling depths through Six Mile and Grand Lakes. These conditions permit barging operations between the Mississippi River at Angola, Louisiana, and the Intracoastal Canal at Morgan City, Louisiana, via the Atchafalaya River without restricting loading depths during the high-water cycle. During the low-water cycle, through barging operations are limited to drafts of 5 to 8 ft.

Commerce

Sea food, steel products, products of forests, dredge shell, and oil account for most of the reported commerce on the Atchafalaya River below Morgan City. Supplementing and complementary to these commodity movements is the large movement of men and supply materials by small vessels in the exploration, development, and production of offshore oil and gas.

Between Morgan City and the Mississippi River, commerce on the Atchafalaya River is largely crude petroleum and refined petroleum products, oil well equipment, steel products, sulphur, salt, and barged logs. Supplementing this reported commerce is also a large movement of men and supply materials by small boats for oil and gas exploration, development, and production. In 1949, the barge movement of crude oil from the oil fields within the Atchafalaya River Basin via the Atchafalaya River totaled approximately 181,530 tons, and was about equally divided between the route upstream and out to the Mississippi via Old River and the route downstream and out via the Intracoastal Canal. In addition, some 112,000 tons of through barge commerce, largely petroleum products from southwest Louisiana and southeast Texas, and destined to Upper Mississippi and Ohio River Valley points, moved via the Atchafalaya River between Morgan City and the Mississippi River at Angola, Louisiana. The reported barge commerce for 1949 was approximately 293,400 tons, and this commerce is increasing.

This renaissance in Atchafalaya River navigation since 1946 may be attributed principally to three factors: (1) development of new oil fields in the Atchafalaya River Basin; (2) towing companies desiring to take advantage of a route that is not congested and is 172 miles shorter than the present route via Harvey Lock, which results in time savings of as much as 3 to 4 days on round trips; and (3) new types of equipment consisting of very powerful towboats and ship-shaped barges which can negotiate the strong currents encountered, without difficulty.

Bayou Plaquemine provided the early navigable approach channel to the Atchafalaya country from the Mississippi River. The removal of the Atchafalaya River "raft" in the 1840-1850 decades and the contemporaneous enlargement of the channel opened the Mississippi-Atchafalaya River route via Old River. Records list the Steamer PANOLA as being the first steamboat to pass out through the Atchafalaya River into the Mississippi River on 20 April 1842. After the closure of Plaquemine Bayou by the construction of a levee across its head in 1865, Old River became the only navigable approach to the Atchafalaya River country from the Mississippi River. Such navigation was restricted to this single route until the reopening of the Plaquemine Bayou route by the construction of Plaquemine, Louisiana, lock in 1909. Commerce to the Atchafalaya River country via Plaquemine Bayou and Old River routes included typical packet boat trade, coal and oil for use in manufacturing sugar, and the movement of timber products. The Atchafalaya-Red River trade reached its peak in about 1887, when there was reported to be approximately 40 million dollars worth of commerce on the Atchafalaya and Red Rivers.

Atchafalaya River dredging

Dredging work performed in Old River and in the Atchafalaya River prior to 1932 was for the specific purposes of improving and maintaining suitable channels for navigation. The maintenance dredging work was confined principally to work in Lower Old River channel and in the Atchafalaya Bay channel at the mouth of Atchafalaya River below Morgan City.

Atchafalaya Bay dredging work at the mouth of the lower Atchafalaya River was initiated in 1870-74 and has been performed intermittently since.

Old River dredging work was initiated in 1888 for the purpose of maintaining a suitable connecting channel for navigation from the Mississippi River to the Atchafalaya, Red, Black, and Ouachita Rivers. This dredging was the consequence of Shreve's Cutoff in 1831, and is of particular significance in that it has provided for the maintenance of the communicating channel between the Atchafalaya and Mississippi Rivers. The status of this channel has an important bearing upon the development of the Atchafalaya River.

Atchafalaya Basin improvement dredging work was initiated in 1932 and improvement dredging work was started in the leveed section of the Atchafalaya River in 1936. This dredging work is of major significance in the improvement of the Atchafalaya River in that it has provided: (1) drainage within the basin section; (2) an excellent navigation channel above the Six Mile and Grand Lakes; and (3) enlargement of the restricted sections within the leveed channel and, consequently, increase in flood-carrying capacity of the Atchafalaya River. This latter work has included enlargement of the constricted sections of the Atchafalaya River at Simmesport, Louisiana, and at Krotz Springs, Louisiana, the removal of sharp points, and the deepening of the channel within the leveed section. In the basin section, the work included the excavation of cutoffs, the rectification and improvement of channels, providing a central channel from the lower end of the leveed channel to Grand Lake, the excavation of Wax Lake Outlet from Grand Lake to the Gulf, and excavation of new and improving existing drainage canals. The borrow pits, excavated in constructing the east and west protection levees in the Atchafalaya Basin, provide continuous drainage, and the east borrow pit channel serves as a navigation channel suitable for inland navigation.

The history and chronology of dredging work performed in Atchafalaya Bay to improve and maintain the navigation channel to the mouth of the lower Atchafalaya River is summarized in the report "Survey of the Atchafalaya River, Morgan City to the Gulf of Mexico, Louisiana," dated 30 April 1948.

The history of the maintenance dredging work performed in Old River is contained in the Annual Reports of the Chief of Engineers and is chronologically summarized in the "Extracts" accompanying this report. Plate 20 of this report shows the principal locations within the Old River channel wherein dredging work was normally performed during the low-water season. Plate 21 shows the location of Carr Point Cutoff as constructed in 1944 and the location of the sand fill that was constructed across the abandoned arm of Old River in 1946.

The map history of Shreve's 1831 Cutoff and the adoption of the relic of the lower arm of the abandoned bend circumscribing Turnbull's Island as the communication channel (Old River) between the Mississippi, Atchafalaya, and Red Rivers is depicted on Plate B78 of Appendix B.

The work performed in the Atchafalaya River from Mile 0 to Mile 110 since 1932, exclusive of the Wax Lake dredging, is shown in plan with dates and yardage quantities listed on Plate B83 of Appendix B. The enlargement of the restricted sections at the Simmesport and Krotz Springs bridges is shown on Plate B80 of Appendix B. The enlargement of the cross sections at Simmesport bridge is also shown on Plate B82 of Appendix B. The summary of dredging operations in the Atchafalaya River and Basin since 1 July 1932 is shown on Plate B83 of Appendix B.

The channel work in the interior portion of the basin had the general purpose of improving the flow capacity of the mid-section of the basin, in which locality the Atchafalaya River was spread into numerous inefficient channels causing a delta formation which was favorable to silting. These improvements provided sufficient channel dimensions for small craft and barge tows at any season or river stage, while sufficient draft is available for larger vessels during periods of high water. The channels excavated ranged from 200 to 750 ft. in width, with bottom elevation from 3 to 35 ft. below mean Gulf level.

The dredging work performed within the Atchafalaya River Basin from Alabama Bayou, Mile 57.0, to Grand Lake, Mile 100, was designated the Atchafalaya River Channel Extension and Enlargement Work and was initiated under the general philosophy of the following four concepts:

(1) Providing a reasonably direct main channel below Alabama Bayou, and making a series of cutoffs in the existing channels;

(2) Improvement of this channel and its branches or feeders;

(3) Agitation dredging to deepen and enlarge main channel;

(4) Development of auxiliary channels to supplement the initial or main channel.

The first channels selected for the initial development were Butte La Rose Cutoff, Bayou LaRompe, Lake Chicot, Lake Long-Fausse Point, Big Tensas-Logan Chute channel, and Cowpen Bayou-Little Tensas channel. However, as the work progressed, plans and methods were modified. Agitation dredging work was discontinued after being found unsuccessful. The originally selected main route was modified to provide for an extension of the main Atchafalaya River channel via Whiskey Bay Pilot Channel, Whiskey Bay Pilot Channel Extension, Blind Tensas Cut, Lake Mongoulois, thence generally by previously selected route to Grand Lake via Myette Point.

One of the initial concepts envisioned the high ground south of Grand River acting as a barrier to flood flows that extended directly across the middle third of the floodway from Butte La Rose, Louisiana, to the crossings of the East Atchafalaya protection levee. It was noted that in time of high water this barrier tended to force the water to the west side of the floodway and to force the water against the west side protection levees. Further in this connection, it is noted that there were no large natural channels bifurcating from Grand River in the mid-section of the floodway to assist in carrying the floodwaters directly southward to Grand Lake. Working in these premises, Cowpen Bayou and Little Tensas cuts were first made through the high ground on the south side of Grand River. Later, Big Tensas and Logan Chute channels were enlarged as an outlet to Upper Grand River and became a part of the Atchafalaya Basin main channel.

Dredging in the leveed section of the Atchafalaya River, Mile 0, to Alabama Bayou, Mile 57, was performed at twenty places and was performed for the specific ~~purpose of: (1) removing the major constrictions within the~~ existing channel; (2) deepening the existing channel; and (3) improving flow conditions by removing protruding points. The locations, date of performance, and amount of this work are shown on Plate B83, Appendix B.

The dredging work performed in the leveed section of the Atchafalaya River, in the Atchafalaya Basin main channel, and in the Atchafalaya Basin, miscellaneous, all since its initiation in 1932, totals approximately 127,000,000 cubic yards and is summarized in Plate B83, Appendix B. The excavation of Wax Lake Outlet required some 53,000,000 cubic yards of additional dredging work.

Transportation and Utilities

In addition to effecting the maintenance of channels suitable for present barge and deep-draft navigation on the Mississippi River below Old River and for barge commerce on the Atchafalaya River, the flow regimen on the Mississippi and Atchafalaya Rivers vitally affects the maintenance of surface transportation, including transcontinental and local highways and trunk-line railroads; likewise, the maintenance of gas, petroleum, power and communication utilities lines; fresh water supply for cities, towns, and industrial plants; sewage and waste disposal for cities, towns, and industrial plants; docking and terminal facilities, etc.

Mississippi River below Old River, Louisiana

Below the latitude of Old River, the Lower Mississippi River channel is relatively stable under the present flow conditions. Channel requirements for the large volume of barge and deep-draft navigation, some 10 million and 25 million tons respectively, are now met by the low-water dredging at: (1) 1 to 3 crossings above New Orleans; (2) dredging in New Orleans Harbor and the Plaquemine, Industrial, and Harvey Lock forebays and tailbays; and (3) high-water dredging at Mississippi River passes.

Railroad transportation is maintained across the Mississippi River via the Baton Rouge and New Orleans bridges. Highway transportation crosses the Mississippi River by means of these same two bridges, supplemented by numerous local ferries. Gas, oil, power, and communication lines cross the Mississippi River at many locations below Old River. In addition to the concentration of dock and wharfage facilities in the ports of Baton Rouge and New Orleans, there are docking facilities established at many other locations along the Lower Mississippi River below Baton Rouge, Louisiana, to provide barge and deep-draft transportation for nearby industrial plants. Mississippi River water has numerous industrial and domestic uses. It provides the fresh water supply for the cities of New Orleans and Algiers, Louisiana, and certain smaller communities located along the river. Its industrial uses include sugar and oil refineries and power plants. It is used agriculturally to irrigate rice. It is also used for sewage and industrial waste disposal.

As a fresh water supply for the cities of New Orleans and Algiers, the present flow distribution prevents contamination of the fresh water by salt water intrusion except in extremely long low-water years when a salt water wedge sometimes extends upstream to and above the present water intakes for New Orleans and Algiers. The fresh-water flow of the Mississippi River is important to the maintenance of the proper fresh water-salinity cycle for oyster beds in the Breton Sound area.

Atchafalaya River, head to Morgan City, Louisiana

The Atchafalaya River channel is unstable from its head to Morgan City by virtue of its progressive enlargement in some sections and shoaling trends in others. The maintenance of suitable navigation channels through this section of the Atchafalaya River is important to navigation interests and to the local people in the Atchafalaya Basin who use the waterway as their only means of communication and transportation.

The maintenance of railroads and highway transportation across the Atchafalaya River and basin is vital to westbound highway and railroad transportation out of New Orleans and Baton Rouge areas, and to the maintenance of local transportation. The river is crossed by four trunk-line railroads, three U. S. highways, and two important state highways. The railroads cross the Atchafalaya by bridges located at Morgan City, Krotz Springs, Melville, and Simmesport. Highways cross by bridges over the Atchafalaya River at Morgan City, Krotz Springs, and Simmesport. Interstate and state oil pipelines, gas pipelines, telephone and telegraph lines, and power crossings exist at some 20 locations on the Atchafalaya River. The location and designation of each of these transportation facilities and utility crossings are shown on Plate B79 in Appendix B. In addition, there are a number of oil loading terminal facilities for barge transportation to and from the many oil and gas fields located along the Atchafalaya River. Terminal and wharf facilities for barges and small craft are located at Morgan City and Berwick, Louisiana. The Intracoastal Waterway crosses the Atchafalaya River and Wax Lake Outlet in the vicinity of Morgan City.

The maintenance of many of the utility lines and railroad bridges crossing the Atchafalaya River has been difficult in the leveed section between Simmesport and Alabama Bayou, Louisiana. The maintenance of the bridges and submarine crossings has been difficult and expensive in many instances, particularly during major Mississippi River floods. The progressive widening of the Atchafalaya River in the upper reaches will require the movement of certain industrial facilities now located adjacent to the channel.

Red River

Comparison of survey data over a 58-year period of record shows small change in channel characteristics of Red River. Generally, the trend has been a decrease in capacity at bankfull and mean low-water stages due to lesser depth with minor increases in width. This period of comparison is antedated by significant man-made works in the area under study, such as the removal of Red River raft in 1828, Shreve's Cutoff in 1831, removal of the Atchafalaya River raft in 1840-55, the construction of two sill dams in the Atchafalaya River about 1888-89, and the construction of a sill dam in Turnbull Bend in the Mississippi River then serving as an outlet of Red River in 1891. Man-made works upstream from the area under study and affecting flood flow through the lower reaches of the Red River were the construction and strengthening of the west bank Mississippi River levees and the closure of the Cypress Creek gap, both of which prevented Mississippi River water from entering the Boeuf-Tensas Basin which forms a part of the Red River Basin.

ANALYSIS OF PROBLEM

Flood Control

The design project for control of floods in the Lower Mississippi River is based on a discharge of 3,000,000 c.f.s. which must be provided for below the latitude of the junction of Old, Red, Mississippi, and Atchafalaya Rivers. The authorized plan wisely utilizes the maximum capacity of the Mississippi River and provides for the discharge of the balance through the Atchafalaya Basin. Experience during prior ~~floods, and engineering data, establishes the fact that the discharge of the~~ Mississippi River between Morganza, River Mile 275 A.H.P., and Bonnet Carré, River Mile 130 A.H.P., should be limited to 1,500,000 c.f.s., of which 250,000 c.f.s. is discharged through the Bonnet Carre Spillway into Lake Pontchartarin and the balance of 1,250,000 c.f.s. is carried past New Orleans, Louisiana, at a stage not in excess of 20 ft. on the Carrollton gage, and thence out into the Gulf via the various passes. This discharge can and has been carried under existing conditions without undue difficulty.

The river between the head of Old River and Morganza under the project plan must carry the above-mentioned 1,500,000 c.f.s. plus 600,000 c.f.s. that is to be discharged through the Morganza control works (now under construction) into the Atchafalaya Basin. Thus, this stretch of river, approximately 25 miles in length, must carry under maximum flood conditions a discharge of 2,100,000 c.f.s. Any deterioration in this carrying capacity reduces the effectiveness of the Morganza control structure. If deterioration in this reach of the Mississippi River becomes marked and results in material reduction of its present capacity, the utilization of the lower river, including Bonnet Carré, in the discharge of floodwaters will be affected adversely. Loss in discharge capacity of the Mississippi River below Old River would force additional waters to be discharged either through the Atchafalaya River channel or through the West Atchafalaya overbank floodway.

The most advantageous solution of the Old River and Atchafalaya River problem from a flood control standpoint would be the maintenance of the maximum discharge capacity of the Mississippi River and the development of the maximum capacity of the Atchafalaya River itself by action of the natural laws applicable to stream flow. Such a solution, however, appears unobtainable, due to the fact that any increase in discharge in one outlet must withdraw flow from the other.

The loss of flow in the Mississippi River below Old River would be accompanied by a deterioration or reduction of channel cross section in its upper reach unless the flood elevations at the latitude of Old River are raised to provide additional slope for the development of velocities that would prevent deposits of suspended sediment and bed load. Maintenance of the existing capacity of the Mississippi River below Old River, combined with an increased capacity in the Atchafalaya River, would result in lower flood elevations at Old River. Lowered flood elevations at this latitude must provide flatter slopes and lesser velocities, unless compensating greater depths are obtained in the first 25 miles of the Mississippi River below Old River. Flatter slopes and reduced velocities in this reach of the river would result in deposit of fill in the channel. These deposits would reduce depth of flow and cause a reduction in the present hydraulic efficiency of this reach of the Lower Mississippi River. Loss of hydraulic efficiency in the Mississippi River would make it necessary for additional flow to pass through the Atchafalaya River, and until its maximum efficiency has been developed it would cause an increase in water elevation in the Red River backwater area between Tarberts Landing and Simmesport. This increase in stage would be relatively temporary, since steeper slopes through the Atchafalaya would develop the hydraulic efficiency of the river and flatten slopes between Simmesport and Morgan City. These flatter slopes through the Atchafalaya Basin would further increase the inflow from the Red River backwater area.

Since the quantity of water available for supplying the Atchafalaya and Mississippi Rivers is limited, the increase in discharge at Simmesport would expedite the deterioration in the Lower Mississippi River between Old River and Morganza, Louisiana. The ultimate result of the recurring cycle of fluctuation between deterioration and improvement would be the elimination of the Lower Mississippi River as an important outlet for floodwaters. If this should occur, it would then be necessary to pass the greater portion of the 3,000,000 c.f.s. inflow through the Atchafalaya Basin. The Atchafalaya River channel cross-sectional area would then have to be much greater. The guide levees and the protection works at Morgan City and Berwick, Louisiana, would have to be raised to provide flood protection during the period of time needed for the full development of a new Mississippi River flood outlet through the Atchafalaya Basin. The existing levees along the Atchafalaya River would have to be reconstructed or abandoned; Simmesport, Melville, Krotz Springs, Morgan City, and Berwick would, in whole or in part, have to be moved. Lower flood elevations in the Mississippi River at Old River caused by maximum development of the Atchafalaya Basin outlet could introduce steeper upstream slopes in the Mississippi and Red Rivers and make the stabilization of these channels more difficult in the reaches below Vicksburg, Mississippi, and Alexandria, Louisiana.

The construction of controlling levees through the Atchafalaya Basin to the presently designed grade and section is extremely difficult. There are many miles of these levees that have been added to at least three times, and they are now barely up to a grade required to pass a discharge of 1,000,000 c.f.s. through the basin, instead of the required 1,500,000 c.f.s. During this natural development period the Mississippi River would be deteriorating at a rate which might be greater or less than the corresponding improvement through the Atchafalaya Basin. The occurence of a flood approaching the project flood during this transition period could result in levee crevasses along the Mississippi River between Old River and Bonnet Carre, or overtopping and crevassing of the floodway controlling levees through the Atchafalaya Basin.

The immediate need for adequate control of floods passing through the Atchafalaya Basin makes it necessary to perform dredging for the development of a channel or channels with cross-sectional areas sufficient to carry the project flood flow through the Atchafalaya Basin below the end of the Atchafalaya River levees without raising the elevation of the flood flow lines above the confining elevations provided by the guide levees. This dredging probably would increase the possibility that the Atchafalaya River will become the main outlet of the Mississippi River. If normal or natural laws applicable to stream flow are permitted to continue to operate without control, there must be a reasonable period of time during which the project flood at the latitude of Old River cannot be safely passed to the Gulf without overflow of protected lands and property and possible loss of life.

Navigation

Some of the most important and difficult problems that will result from the increasing diversion of Mississippi River flow through the Atchafalaya River will arise in connection with maintaining suitable navigation channels. The Mississippi River-Atchafalaya River flow regimen directly affects channel conditions on the Mississippi, Atchafalaya, Red, and Ouachita Rivers, and the Intracoastal Canal.

On the Lower Mississippi River, the present requirements of barge and deep-draft navigation are met by maintaining a 9-ft. by 300-ft. channel above Baton Rouge, Louisiana, and a 35-ft. by 500-ft. channel below Baton Rouge, with a 35-ft. by 1500-ft. channel through New Orleans Harbor. Approved projects provide for deepening the barge channel above Baton Rouge, Louisiana, to 12 ft., and the deep-draft channel to 40 ft. below New Orleans, Louisiana.

Normal maintenance of these minimum channel dimensions from 50 miles above Old River to the Gulf require: (1) occasional low-water dredging of crossings at two locations, Miles 354 and 345 A.H.P., respectively; (2) occasional low-water dredging of crossing at Hog Point, Mile 296.5 A.H.P.; (3) annual low-water dredging of crossing at Red Eye, Mile 223 A.H.P., and occasional low-water dredging of crossings at one or two other locations between Baton Rouge and New Orleans, Louisiana; and (4) annual high-water dredging at the Mississippi River Passes.

The vital 12-ft. by 125-ft. Intracoastal Canal channel, New Orleans to Wax Lake Crossing, ~~is maintained by: (1) annual dredging in the forebays of Industrial~~ Canal and Harvey Canal; (2) tailbay dredging at these locks as required; and (3) dredging in the canal channel at about 5-year intervals. A 9-ft. by 100-ft. channel is similarly maintained between Morgan City and Plaquemine, Louisiana.

No navigation requirements are anticipated for the Red River above the mouth of Black River until construction of the Overton Canal project is initiated.

On the Ouachita-Black River, a 6-1/2-ft. depth channel is now maintained to Camden, Arkansas. Deepening of this waterway to 9 ft. is authorized.

The Atchafalaya River above Morgan City, Louisiana, together with Old River, has become an important navigation artery. Navigation interests are using the Old-Atchafalaya River route whenever depths through the Grand-Six Mile Lake reach permit. Traffic through the Grand-Six Mile Lake reach is limited by a depth as little as 5 ft. in low water. Numerous requests have been made for navigation dredging in this reach so that this route can be used at all river stages. A channel through the shallow water of Grand-Six Mile Lake has been buoyed to facilitate navigation. The use of this buoyed channel by navigation may assist the river in developing a single efficient channel through this reach. Any dredging that may be performed for maintenance of this navigation route will also expedite the development of this main channel.

The need for improvement of the Atchafalaya River from Morgan City, Louisiana, to the Mississippi River via Old River for navigation purposes has already resulted in the submission of a report recommending the adoption of a 12-ft. by 125-ft. channel. There is an existing project to provide for a navigable channel 20 ft. deep and 200 ft. wide, to extend from the -20-ft. contour, mean low Gulf level, in the Atchafalaya Bay to the same contour in the Gulf of Mexico. Old River is also a link in authorized or existing navigation projects on the Ouachita and Red Rivers, including the Overton Canal to Shreveport, Louisiana.

Progressive increase in the diversion of Mississippi River flow via the Atchafalaya River will, through changes in water surface slopes, shoaling rates, and lower high-water planes and current velocities, materially affect navigation conditions in the routes discussed above.

The gradual deterioration of the Mississippi River channel below Old River by increased shoaling would increase present dredging requirements to maintain barge and deep-draft navigation below Old River, and if permitted to continue would ultimately cause Mississippi River commerce en route to and from New Orleans to points above Old River to be diverted via Morgan City.

Ultimate increases in slope and velocities in the Mississippi River channel above Old River would set up very unfavorable navigation conditions in that reach of river. These unfavorable navigation conditions would work progressively upstream.

Lowering of the low-water plane in the Old River area would change the regimen of lower Red River and of Black River.

Raising of the high-water surface elevation in the latitude of Morgan City would ultimately require the construction of navigation locks for the Intracoastal Canal at its confluence with the Atchafalaya River and possibly at the Wax Lake Outlet.

Thus, unless the Mississippi River-Old River-Atchafalaya River flow regimen is controlled sufficiently to prevent the Mississippi River from adopting the shorter route via the Atchafalaya River, unfavorable navigation conditions will occur in the affected channels, particularly the Lower Mississippi River downstream from a point about 50 miles above Old River, and will require additional maintenance work.

Present and prospective Atchafalaya River barge commerce makes it necessary that any measures adopted to improve or regulate flood flows in the Atchafalaya River give appropriate consideration to the needs of navigation, both local traffic originating within the basin itself, and through commerce.

Land Transportation and Utilities

The enlargement of the Atchafalaya River by nature or by man-made works to permit the present combined flow of the Mississippi and Atchafalaya Rivers to pass through the Atchafalaya Basin would necessitate the relocation or major alteration of three important highways, three trunk railroad lines, and numerous power and pipeline crossings, together with the extension and possible reconstruction of all existing bridges crossing the river. Industrial and municipal and Federal improvements now located adjacent to the river at Simmesport, Melville, Krotz Springs, Berwick and Morgan City, and Calumet and Patterson would have to be relocated to provide additional channel widths. The increased flood flow in the lower Atchafalaya River caused by the diversion of Mississippi River flow through the basin would also submerge the marsh areas between Houma and New Iberia.

The reduction in the present low-water flow now passing New Orleans, Louisiana, would increase the salinity of the Mississippi River at low stages and could ultimately make it necessary to provide a new source of water supply for the city of New Orleans. The loss of stream flow in the Mississippi River could and would properly require costly treatment of both municipal and industrial sewage now being dumped into the river. The river is now used for the release of untreated waste, and any material reduction in the volume of low-water flow could result in very obnoxious conditions along the river.

GEOLOGY AND ANALYSIS OF ENGINEERING DATA

Early History

Review of available engineering and geological data establishes the fact that the Mississippi River has at one time occupied the relatively high ridge originating east of Bunkie, Louisiana, and presently known, in the lower end of the Atchafalaya Basin, as the Teche ridge. The river later abandoned this course to the sea by adopting a course east of the Marksville Highland, thence to the vicinity of Donaldsonville, Louisiana, thence via the Lafourche ridge to the sea. Still later the Mississippi River abandoned the course along the Bayou Lafourche ridge for a more favorable course, generally along its present course, until it reached New Orleans, Louisiana, where it again debouched into the sea via Bayou la Loutre. Later this outlet, between Lake Borgne and Breton Sound, was abandoned for its present outlet through the existing passes.

The comparatively high lands along the Lafourche and Teche Bayous are the result of natural deposits or natural levees constructed with materials transported from the vast drainage areas of the Mississippi River. After the Mississippi River had abandoned these old courses, these deposits functioned as confining levees for moderate floods, leaving large areas between these ridges exposed only to relatively minor deposits of fine material.

The area now known as the Atchafalaya Basin lies between two of these former courses of the Mississippi River: the Teche ridge course and the Lafourche Bayou course, and is bounded on the upstream side by the existing natural levee of the Mississippi River. The area in general is composed of back-swamp and point-bar deposits underlain by erodible sand with top elevation ranging from about +20 feet m.s.l. at the upper end to about -120 feet m.s.l. in the Grand Lake area, except for two locations where old meanders of the Mississippi River are filled with channel deposits. One of these locations is at Simmesport and the other is presently known as Cypress Point.

After the Mississippi River had abandoned its courses along the Teche and Bayou Lafourche ridges, the excess water spilled over these natural ridges into the low area now known as the Atchafalaya Basin. This resulted in the development of numerous small distributary channels feeding into the lower ground in the basin. Earliest engineering reports indicate that these channels had merged by 1774 into a more or less general channel, known as the "Chafalia," which extended down as far as Bayou Pigeon. The area between the lower end of the "Chafalia" and the sea probably consisted of a myriad of lakes with a more or less uniform elevation slightly above mean sea level. Grand Lake then extended up as far as Ramah, approximately 44 miles below the head of the present Atchafalaya River (Plates A4-A7, Appendix A).

Unfavorable flow conditions, probably overbank or natural levee crevasses, limited discharge from the Mississippi River to a relatively minor quantity. This restricted discharge, though minor, ultimately resulted in an improvement, and additional water passed into the Atchafalaya swamps. These crevasses or spillways through the Mississippi River natural levees were finally collected into one channel which became known as the Atchafalaya River, and which, due to its favorable angle of departure from the Mississippi and Red Rivers, collected a vast amount of debris that finally extended as a raft from bank to bank for some 30 miles from the river's head. This choked condition regulated or controlled the enlargement of the river for many years, but the restriction of flow resulted in flooding of improved lands, and the need for a navigation route finally became so urgent that the raft was removed by the State of Louisiana to the extent that the river became navigable. This removal was completed by 1855.

Humphreys and Abbot report that during the flood of 1858 the discharge of Red River into the Old River area was just sufficient to maintain the normal discharge of Bayou Atchafalaya, which was estimated to be about 120,000 cubic feet per second. The discharge of the Atchafalaya River steadily increased and by 1870 some engineers interested in the Lower Mississippi Valley feared that the Atchafalaya River might capture the Mississippi River. This fear finally became so strong that two sill dams were constructed in the river near Simmesport for the control of low-water flow into the Atchafalaya so that the Mississippi River itself would have full advantage of the maximum available low-water flow.

Channel Enlargement

Atchafalaya River

Accurate or reliable survey data on enlargement of channel cross sections of the Old and Atchafalaya Rivers prior to 1880 are very meagre. One old report states that in 1839 the Atchafalaya was so narrow near its head that a person could walk across it with the aid of a long plank. Survey data indicate that in 1880 the low-water cross-sectional area at Simmesport was 17,800 sq. ft. and the bankfull area was 49,670 sq. ft., with widths of from 660 to 985 ft. and mean depths of 27 to 50 ft. for low and bankfull stages, respectively. The 1932 survey shows the cross-sectional area to be 26,900 sq. ft. at low water and 69,960 sq. ft. at bankfull, with widths of 910 and 1,305 ft. at low and bankfull stages, respectively. The 1950 survey shows a low-water cross-sectional area of 33,800 sq. ft. and a bankfull area of 87,980 sq. ft., with widths of 1,160 and 1,695 ft., and depths of 29.7 and 54.0 ft. at low and bankfull stages, respectively.

The average cross-sectional areas on the Atchafalaya River for the reach between Mile 37.9 and Mile 42.9 as shown by the 1880 survey were 11,600 sq. ft. and 21,100 sq. ft. for the low-water and bankfull stages, respectively. The average widths of this reach in 1880 were 405 and 525 ft. for the low and bankfull stages, respectively. The mean depths for these stages were 28.6 and 40.2 ft. The 1880 survey did not extend further downstream. The 1932 survey for this reach shows the low and bankfull cross-sectional areas had increased to 36,800 and 54,500 ft., respectively. The average widths in the reach for these stages in 1932 were 845 and 975 ft., and the mean depths were 43.6 and 55.9 ft. for the low and bankfull stages, respectively. The 1950 survey shows the average areas of this reach had increased to 53,660 and 77,650 sq. ft. for low and bankfull stages, respectively. This is an increase of 362.6 percent over the 1880 area in this reach for low water, and 268 percent over the 1880 bankfull area.

Results of the latest surveys, in 1950, show that the high-water cross-sectional areas between the head of the Atchafalaya River down to the head of Whiskey Bay channel, Mile 57, range from approximately 100,000 sq. ft. at its head to 80,000 sq. ft. at Whiskey Bay. It is estimated that 254 million cubic yards of material were removed from the leveed channel of the Atchafalaya River between 1932 and 1950. Some 22-1/4 million cubic yards are attributable to improvement dredging in the leveed channel, and the balance of about 232 million cubic yards is attributable to scour. The average depths, at low water, of the various reaches throughout the entire 57 miles above Whiskey Bay range from 25 to 70 ft., with the minimum depth prevailing in only one reach, approximately Mile 8 to Mile 13. The depths at bankfull stage range from 52 to 80 ft., the maximum depth being at the head of Whiskey Bay. The relatively shallow depth at low water between Mile 8 and Mile 13 reflects the effect of channel deposits in an ancient meander course of the Mississippi River.

Soils boring data develop the fact that the upper Atchafalaya River is underlain by substratum sands with a top elevation or contour varying from -20 ft. near

Simmesport to -100 ft. m.s.l., with the greatest depth being at River Miles 15 and 20. These deeper substratum sands at River Miles 15 and 20 are due to the ancient Mississippi River meander referred to immediately above. The boring data show that the thalweg of the river in its upper 30 miles has, in general, cut through the more resistant backswamp deposits and clays into the erodible substratum sands. This condition should effect a rapid enlargement of the river cross section in its upper reaches.

Between Miles 30 and 57, the head of Whiskey Bay, the river has practically degraded its thalweg channel through the more resistant materials into the erodible sands, except in short reaches where the channel is still in backswamp deposits.

Between the head of Whiskey Bay and the head of Lake Chicot, River Mile 57 to River Mile 80, the improved main channel through Whiskey Bay, upper Grand River, Blind Tensas, Lake Mongoulois, Bayou Chene, and into the head of modern Lake Chicot is nearing the top of the subterranean erodible sands.

Between the head of Lake Chicot and Myette Point, the subterranean sands are found at about -120 ft. m.s.l., while the improved channel is only -20 to -40 ft. m.s.l. The top of the erodible sands through the Grand-Six Mile Lake area is about -120 to -130 ft. m.s.l. The average elevation of the bottom of the existing main channel through this latter reach is about -12 ft. m.s.l.

In 1894, the average cross-sectional area of Old River at bankfull elevation (48 ft. m.s.l.) was 28,000 sq. ft., with a mean depth of 35.3 ft. Little change in cross-sectional area occurred between 1894 and 1908. After 1908, the cross-sectional area had increased an additional 8,000 sq. ft. by 1922, and in 1950 the average cross-sectional area throughout Old River was about 61,000 sq. ft., with a mean depth of 51 ft. and a maximum depth of about 86 ft. This is an increase, in area, of 118 percent of the average area in 1894.

Effect of natural and artificial levees on channel enlargement

Prior to 1874 the development of the main channel of the Atchafalaya River was influenced by the building up of its banks by natural deposit of silts which confined progressively higher stages of flow within the channel. This growth of banks is commonly referred to by geologists as "natural levees" and is so termed in this report. Later, the confinement of flow within the channel in the upper reaches of the Atchafalaya was further improved by the construction of artificial levees, and available data indicate that the confinement of higher and higher stages of the river by both natural and artificial levees was always followed by rapid increase in channel cross sections.

The river is now confined on its left descending bank down to the mouth or head of Alabama Bayou, and on the right descending bank down to River Mile 70, by artificial levees. The west bank levee between Mile 55 opposite Alabama Bayou, and Mile 70, is constructed to confine a discharge slightly less than 1,000,000 c.f.s. through the floodway and the river. The leveed channel above Alabama Bayou to Simmesport under its present hydraulic efficiency will confine a discharge of between 700,000 and 750,000 c.f.s. The confinement of this volume of flow should result in continued rapid improvement of the cross-sectional area and hydraulic efficiency of the upper 70 miles of the river.

The suspended sediments and bed load carried by this discharge are being deposited along the banks of the various channels in the reach below the head of Whiskey Bay. These natural levees, as shown by survey data, are from 15 ft. in height in the upper reaches to a minimum of 5 ft. at the head of Grand Lake, and are now approaching, in places, within 8 ft. of the height of the existing artificial floodway guide levees. These deposits are being rapidly broadened, and the general elevation of the overbank floodway below the leveed channel is being raised. Computations of the quantity of deposits below the end of the levees show that approximately 1-1/2 billion cubic yards have been deposited since 1932.

The increase in capacity for discharge through the upper reaches of the river should increase the future rate of growth of these confining natural levees. It can be expected that as the natural levees become higher, numerous crevasses or spillways will develop which will permit silt deposits to pass into the low, swampy overbank areas, which should cause a rapid reduction in discharge capacity of these overbank areas. Silt deposits passing out of the Atchafalaya River through Alabama Bayou, the many small distributary channels, and upper Grand River are constructing natural barriers across the area over which Morganza Floodway discharge must pass. Silt deposits, if permitted to continue to discharge through these channels, will ultimately enter the East Atchafalaya Guide Levee borrow pits now forming a link in the Morgan City-Plaquemine Waterway. If this occurs, maintenance and navigation dredging of this waterway will be increased. The rapid growth of the natural levees and deposit in overbank areas during the last 18 years has amounted to a reduction of an average of 3.3 feet in the cross-sectional depth of the floodway below the end of the river levees. An allowance for the effect of foundation compression or consolidation has been included in this estimated reduction.

Available data indicate that the river, in the past, has been developing and advancing its channel toward the sea by the natural deposit of river-borne materials and then cutting its way through the ridge at an average rate of about 1/2 mile per year. An increase in the river flow at Simmesport will increase this average rate of advancement of the channel. The recurrence of a flood similar to the 1927 flood, or a sequence of floods similar to the 1945 and 1950 floods within a 10-year period, could cause the natural development of this channel in a much shorter period of time.

Increase in Discharge Capacity

Atchafalaya River

Prior to the removal of the raft in the Atchafalaya River, its discharge was approximately 30,000 c.f.s. This capacity would appear to have been insufficient to take care of local runoff. After removal of the raft, the discharge of the Atchafalaya River increased and, in 1858, the bankfull discharge was about 130,000 c.f.s. By 1890, the bankfull discharge was 270,000 c.f.s. In 1928, it was 325,000 c.f.s.; in 1938, 360,000 c.f.s.; in 1945, 425,000 c.f.s.; and in 1950, 460,000 c.f.s.

The discharge at midbank stage (20 feet on the Simmesport gage) in 1882 was approximately 56,000 c.f.s.; in 1938, it was 155,000 c.f.s.; and in 1950, it was 192,000 c.f.s. This large increase in discharge shows that the capacity of the Atchafalaya River is quite different from the river considered by Humphreys and Abbot on page 405 of their report where they indicate that the closure of Old River would entail disastrous consequences due to the fact that Red River discharge, at its mouth, was 225,000 c.f.s., and the Atchafalaya could only handle 130,000 c.f.s. They feared that the separation of the Red and Mississippi Rivers would result in disastrous overflow in the Bayou des Glaises and Atchafalaya Basins due to the inability of the Atchafalaya River to handle the discharge of the Red River. In other words, the objection to the closure of Old River at that time appears to have been based on the thought that it was necessary to keep Old River open so that excess floodwaters from the Red River could pass down the Mississippi River. This concept of the need for interchange of flood flow is the direct opposite of the concept on which the over-all flood control plan for the Lower Mississippi River is based.

Consideration of maximum discharges into the Atchafalaya Basin prior to 1929 is believed to have little bearing on the solution of the problem being considered in this report. Conditions have been materially changed since 1927 by the construction of more and stronger levees which have prevented crevasses in the Mississippi River and the Atchafalaya River levees. Prior to and during the flood of 1927, water from crevasses in the Mississippi and Atchafalaya River levees was permitted to flow into an unimproved basin extending from the Teche ridge to the Bayou Lafourche ridge, and a large amount of storage occurred in this area. This storage, together with a wide overbank width, permitted the water to flow into the sea without creating excessive flood heights through the basin above Morgan City. This vast overbank floodway area has been restricted since 1932 by the construction of the floodway guide levees which have confined the floodway overbank width to approximately 50 percent of its original width in the reach below the end of the Atchafalaya River levees. The reduction in overbank flow width, in the vicinity of Grand Lake, is even greater.

All flow into the basin since 1927 has passed through the Atchafalaya River leveed channel.

Old River

If the stage of the Mississippi River is high and Red River is low, conditions are most favorable for the flow of water from the Mississippi River to the Atchafalaya. Conversely, a high Red River and a low Mississippi are favorable for flow from the Red River toward the Mississippi River. In the year 1892, flow toward the Mississippi River occurred on 208 of the 365 days. This emphasizes the inefficient flow conditions in the Atchafalaya Basin at that time. Conditions favorable to flow from the Red River to the Mississippi River have not occurred since 1942, during which year this condition existed for only 9 days. This emphasizes the present improved discharge capacity of the Atchafalaya River. The Old River channel has a capacity of about 400,000 c.f.s. at approximately bankfull stage. The maximum flow from the Mississippi River toward the Atchafalaya River was measured in 1937 as 514,000 c.f.s., which includes overbank flow as well as channel flow. The maximum measured flow from the Red River backwater area into the Mississippi River occurred in 1912 and amounted to 310,000 c.f.s., including overbank flow. This latter discharge was largely due to flow through levee crevasses along the Arkansas and Mississippi River fronts and through the unleveed gap known as Cypress Creek, which permitted the Mississippi River to discharge a portion of its flood flow into the Tensas-Ouachita-Red River Basin.

Effect of Sediment and Bed Load

Sediment observations in connection with this study were taken in Old River on 13 November 1950 and, for a discharge of 63,400 c.f.s., 81,700 tons per day of material passed Torras toward the Atchafalaya River, with an average of 477 parts per million. Another observation made 29 January 1951 showed 698,000 tons of sediment per day for a discharge of 249,000 c.f.s., with an average parts per million of 1,039. The average flow through Old River at Torras has been 90,100 c.f.s. toward the Atchafalaya River for the period 1928-1950. For the period 1940-1950, the average flow toward the Atchafalaya River has been 109,400 c.f.s.

Sediment measurements taken in connection with this study and reported elsewhere in this report and its accompanying exhibits indicate that the amount of material being transported by water in the Atchafalaya-Old River is in no way approaching the sediment-carrying capacity of the stream. Measurements of sediment load of several streams in the Missouri River Basin and in the Missouri River itself, at its mouth, show a much greater silt burden.

The angle of diversion from the Mississippi River is in the concave side of a bend. The Mississippi River, in this bend, has a depth of about 70 feet below mean sea level. Old River, immediately below the point of diversion, has a shallower depth which serves as a sill or weir and tends to prevent the heavier bed load from entering the Old River channel. The lower portion of the flow carrying the bed load should pass down the Mississippi rather than into Old River. The diversion into Old River, in general, is being supplied from the upper layers of flow which carry only finer suspended material, and it would appear that an increase in discharge through Old River would result in an increase in the suspended load that is now being transported into the lower Atchafalaya Basin below the end of the leveed channel with no great increase in bed load.

Trial or preliminary computation of bed-load material transported in the upper Atchafalaya River, as derived from Einstein's formula, using discharges on dates that sediment samples were taken indicates the following results: A discharge of 126,000 c.f.s., carrying a suspended load of 236,800 tons per day, would produce a bed load of 56 tons per day; for a discharge of 141,000 c.f.s., with a suspended sediment load of 167,500 tons per day, the bed load would be 310 tons; and for a discharge of 333,000 c.f.s., carrying a suspended load of 891,900 tons per day, the bed load would be 11,400 tons. These results indicate that the amount of bed load now passing into the Atchafalaya River at Simmesport represents a minor part of the silt deposits forming in the lower basin. Available data on suspended and bed load indicate that little restriction on the enlargement of the leveed channel of the Atchafalaya River can be expected from filling or choking by excessive deposits.

Salinity

The study of salinity records from all stations in the lower Atchafalaya Basin and adjacent coastal areas shows that such a small amount of salinity present could have no deleterious effect on the development of the Atchafalaya River or the use of its waters.

Tides

Hurricane storms have, in the past, caused high tidal stages at Morgan City approximately equal to those occurring during high-water periods. Tidal action is usually credited with the development of the efficient channel through Berwick Bay, and an increase in the depth of the Wax Lake Outlet to those prevailing through Berwick Bay will probably result in tidal maintenance of another deep channel through the Teche ridge at Wax Lake. Tidal action will also operate toward development of deep passes in the Atchafalaya Bay, when or if the Atchafalaya River becomes as fully developed as the main Mississippi River channel outlet. The Atchafalaya River would then begin the extension of its delta into the Gulf.

Slopes

In Old River, since 1942, the normal condition has been favorable for a slope toward Red River of approximately 1.2 ft. at mean low water, and from 0.5 to 1.0 ft. at high overbank stages.

Available data indicate that the slopes in the Atchafalaya River are becoming progressively flatter as the hydraulic efficiency of the leveed channel develops. In 1929, for a discharge of 350,000 c.f.s. at Simmesport, the water surface was 49 ft. m.s.l., and for the same discharge at Atchafalaya, Louisiana, 54 miles downstream, the water surface was 22.5 ft. m.s.l., giving a head differential of 26.5 ft. In 1950, the water surface elevation for a similar discharge was 39.5 ft. at Simmesport, and at Atchafalaya was 26 ft. m.s.l., giving a head differential of 13.5 ft. These comparisons indicate a lowering of 9.5 ft. in water elevation at Simmesport and an increase in elevation of 3.5 ft. at Atchafalaya, Louisiana.

Thus, the hydraulic improvement of the leveed channel between 1929 and 1950 was so great that the river could discharge the same amount of water in 1950 that it did in 1929, with 13 ft. less head.

The increase in stage at Atchafalaya, Louisiana, since 1929 is due to two causes: (1) the extension of the West Atchafalaya River levee from Bayou Courtableau, approximately River Mile 48, to approximately River Mile 70, being a downstream extension of the west river levee of approximately 18.5 miles; and (2) the deposit of silt load in overbank areas, small connecting channels, and confinement of flow within channels restricted by natural levee deposits. In 1950, the average slope through the upper 54 miles of the river, for a discharge of 350,000 c.f.s., was about 0.25 ft. per mile. The extension of the hydraulically efficient channel from Mile 54 to the Gulf of Mexico via Morgan City, of the capacity needed to discharge 350,000 c.f.s. with this same slope per mile, would require a head differential of only 18.75 ft. The slope available under 1950 conditions is 26 ft., or a head surplus of some 7.25 ft.

The head differential needed for the development of an efficient channel via Wax Lake Outlet to the Gulf, with the same slope conditions as those existing above Atchafalaya, Louisiana, gage in 1950, would require a head differential of only 14.75 ft. There is available a surplus head of approximately 11.25 ft. There is no indication from available data and comparison of the hydraulic efficiency of the Mississippi River in the New Orleans reach to show that the leveed reach of the Atchafalaya River has attained its minimum slope. It can be expected that as the channel through the leveed section enlarges, the slope will become flatter, due to lowering of the flow lines in the upper reaches and the raising of flow lines below the end of the levees. This progressive action will continue until the river has developed an adequate and efficient channel through the lower basin to the head of Wax Lake and Stouts Pass.

Continued deterioration of channel and overbank flow conditions between Whiskey Bay, River Mile 57, and Myette Point, River Mile 96, will cause an additional increase in flood flow elevations, through this reach, and unless corrected by nature or by improvement dredging, will result in the overtopping and crevassing of the floodway guide levees. An increase in levee grade, to compensate for this increase in flood flow elevations, is not practicable. These levees are located in swampy area and have been under construction for 18 years, and they are now just high enough to confine a discharge of 1,000,000 c.f.s. through that portion of the basin lying between the end of the Atchafalaya River levees and the two outlets through the Teche ridge, without infringing on the design freeboard.

Wax Lake Outlet

The Wax Lake Outlet was constructed for the purpose of providing an additional outlet through the Teche ridge in order that the improved land on the Teche ridge east and west of Morgan City, Louisiana, could be protected without raising flood stages at Morgan City beyond those contemplated in the 1928 project act. It was designed to provide a discharge capacity of 270,000 c.f.s. when a project flood diversion of 1,500,000 c.f.s. was passing through the Atchafalaya Floodway. Discharge observations of the larger floods occurring since its completion in 1941 indicate that the Wax Lake Outlet is discharging the quantity of water it is designed to discharge under the varying flood stages, and it will discharge 270,000 c.f.s. under project flood conditions. Inspection of cross sections taken in 1950 indicates there may be a slight trend toward enlargement of this outlet, but this is merely an indication of a trend toward improvement and shows there has been no deterioration.

It is noted that that portion of Six Mile Lake lying between Cypress Island and Wax Lake is rapidly filling with silt. This condition is not a favorable entrance condition for maximum discharge through Wax Lake Outlet. Rapid deposit of silt in this area during low-water seasons, however, would probably destroy any dredged channel that might be provided at this time or in the immediate future. Siltation in this particular reach may be so heavy within the next five years that the deposit will build up to low-water elevation, after which a channel leading from the vicinity of the upstream end of Cypress Island to Wax Lake can be provided, with some assurance that it will not require frequent redredging.

Berwick Bay

Data on the discharge capacity of the Berwick Bay Outlet are limited, due to the fact that prior to the passage of the 1928 Flood Control Act, the Atchafalaya Basin was not under the direct supervision of the Mississippi River Commission. The earliest discharge measurements by the Mississippi River Commission at Morgan City were those taken during the flood of 1927. The maximum observed discharge of 703,000 c.f.s. occurred in 1927 at a stage of 9.6 feet on the Morgan City gage. The maximum stage of record, 9.7 feet at Morgan City, also occurred during the 1927 flood. Discharge observations made since 1927 indicate that the Berwick Bay Outlet to the Gulf can pass 1,200,000 c.f.s. when project flow line elevations occur in that reach. The combined discharge of the two outlets through the Teche ridge appears to be adequate for the passage of project flood flow from the Atchafalaya Basin to the Gulf without exceeding project flood design flow lines in that latitude.

Effect of Increased Stages Below the Leveed Channel on Inflow at Simmesport

The critical reach with respect to flow line elevation and slope lies between the head of Whiskey Bay and the latitude of Morgan City. As stated hereinabove, flood stages on the Atchafalaya, Louisiana, gage have increased 3.5 ft. since 1929. This increase in stage produces a backwater effect in the leveed channel of the Atchafalaya River. The possibility that further increase in flood heights in this reach might produce a stabilized condition in the leveed channel has been investigated. Assuming a discharge of 600,000 c.f.s. at Simmesport under both the 1945 and 1950 conditions, it was found that the 1950 stages at Atchafalaya, Louisiana, were about 2 ft. higher than in 1945. Again, assuming that the Atchafalaya River and floodway levees were able to confine further increases in stage at the end of the levee, and stages did increase an additional 5 ft., the backwater effect at Simmesport would be approximately 1.0 ft. It would require a 10-ft. increase in stage at the end of the leveed channel to produce a backwater effect of about 3.0 ft. at Simmesport.

It is reasonable to assume that the Atchafalaya River in its leveed reaches will continue to improve hydraulically during the time required for nature to deteriorate conditions at the end of the levee sufficient to produce either a 5- or 10-ft. increase in stage. It is of course obvious that an additional increase in flow line elevations in the vicinity of Atchafalaya, Louisiana, of considerably less than 5 ft. would overtop the Atchafalaya River levees and would undoubtedly result in overtopping the existing floodway guide levees when inflow from the latitude of Old River approached project flood dimensions. This condition appears to make it necessary to assist the Atchafalaya River in the development of an efficient channel through the middle reaches of the basin by improvement dredging at an early date.

Distribution of Flow

The natural topographic features within the leveed floodway, the prior improvement dredging, and the recent extension of the west Atchafalaya River levee, all tend to direct flood flow toward the east side of the floodway. The improvement dredging and the riverside borrow pits excavated for guide levee construction, presently utilized as navigation channels, provide three main flood flow distribution arteries below upper Grand River which partially overcome the tendency toward concentration of flow in the east side of the floodway.

At the head of Bayou Chene Cut, the middle or main channel and its projected overbank area in 1950 carried approximately 290,000 c.f.s., while the east side borrow pit channel and its overbank areas carried 130,000 c.f.s. and the west side borrow pit channel, adjacent overbank areas, and improved dredged channel carried 190,000 c.f.s.

~~In the latitude of Fisher's Island, the main channel in 1950 carried approxi-~~ mately 270,000 c.f.s. The east side borrow pit channel and overbank areas carried 190,000 c.f.s. and the west channel, with the improved dredge cut, carried 150,000 c.f.s.

In the latitude of Cypress Island, Grand Lake and the Cypress Island Pass carried 380,000 c.f.s. in 1950. Bayou Boutte with its adjacent area carried 100,000 c.f.s., and the east overbank area and the navigation canal along the levee carried 150,000 c.f.s.

In the latitude of Morgan City, Wax Lake Outlet carried 145,000 c.f.s. and Berwick Bay at Morgan City carried 485,000 c.f.s. in 1950 (Plate B53, Appendix B).

Plate B53 also shows that the middle channel flow and the west side channel flow are combining into one flow channel immediately above Myette Point at a rather oblique angle, causing considerable cross flow at this point. This cross flow is causing the main channel and the lake area to deteriorate in this reach. Enlargement or improvement of entrance conditions should cause the cut to improve so that the combined flow from the main and west channels will flow through it and thence on through the Cypress Island Pass to Six Mile Lake.

Mississippi River

Cross section

The reach of the Mississippi River considered to be pertinent to the problem in this study extends from the vicinity of Black Hawk Landing above the mouth of Old River to below the head of Morganza Floodway. The most critical section of the reach pertinent to the study extends from the mouth of Old River to the upper side of the entrance to the Morganza Floodway, and it is expected that in this latter reach marked deterioration of cross section will occur, first between River Mile 292.5 and River Mile 296.3 A.H.P., and next between River Mile 266 and River Mile 274.

Comparison of cross-sectional areas above Old River shows that between 1882 and 1922 the tendency was toward an increase in the low-water cross-sectional area. This tendency continued until 1938, at which time the river attained its largest over-all cross-sectional area in the reaches above Old River. The 1950 survey indicates a trend toward a decrease in low-water over-all cross-sectional area since 1938 for the three reaches above Old River.

Comparison of cross-sectional areas for bankfull stage indicates the maximum over-all cross-sectional area of the three reaches above Old River occurred in 1937. Since 1937, there has been a slight reduction in over-all cross-sectional area, but the three reaches have a more uniform area of about 212,000 sq. ft. This cross-sectional area of 212,000 sq. ft. compares favorably with the cross-sectional area for bankfull stage in the Mississippi River above this point. Comparison of the mean low-water depths for the three reaches above Old River indicates there has been little appreciable change in over-all mean depth. The greatest over-all bankfull mean depth for the three reaches above Old River occurred in 1935 and 1937, with a slight reduction in mean depth shown by the 1950 survey. The minimum mean depth at bankfull stage occurred in 1895 with an average depth of 52 ft. The average mean depth as shown by the 1950 survey is about 60 ft.

The comparison of low-water cross-sectional areas for the reaches below Old River indicates the maximum over-all average cross section occurred in 1882, being about 84,000 sq. ft. By 1935, the average over-all low-water cross section had decreased to 63,000 sq. ft., and by 1950 it had decreased to 60,000 sq. ft. The greatest average low-water mean depth for the reach below Old River occurred in 1882, with a depth of 39 ft. The 1935 survey shows the average mean depth at low water was 28 ft., and the 1950 survey shows there has been little change in this average mean depth.

The maximum over-all bankfull cross-sectional areas for the reach below Old River, as shown by comparison of survey data, occurred in 1882, with an average area of about 209,000 sq. ft. The 1935 survey shows this average area for the reach had decreased to about 190,000 sq. ft. The 1950 survey shows the average area for the reach to be about 180,000 sq. ft.

The greatest average mean depth at bankfull stage for the reach below Old River occurred in 1882 and was about 61 feet. In 1935 and 1937 it had reduced to about 52 feet, and at present is about 50 feet.

All data on cross sections in the Mississippi River reach, adjacent to Old River, indicate that the Mississippi River is adjusting its channel to conform with the increased discharge capacity of the Atchafalaya River.

In addition to the changes that occur in cross-sectional areas of the river over long periods of time, there is also a change in the areas during an individual flood. These temporary scour or fill changes in the Mississippi River cross sections during a flood are not restricted to the river in the vicinity of the Old River diversion but are noted in the observations at all the regular discharge ranges. Changes in areas are normally due to sand waves moving down or across the river; caving banks in the immediate vicinity; temporary deposits due to alignment changes; obstructions in the river bed that create unusual turbulence; and diversions when the discharges are of such a character that they create a slackening in the mean velocity of the discharge below the point of outflow from the main stream and which, in turn, causes sediment to deposit temporarily in the main channel section.

Discharges

Flood discharge records on the Mississippi River at Red River Landing prior to 1893 were influenced by crevasses in the levees further downstream. Eliminating maximum discharge measurements prior to 1893, it is found that a discharge of 1,400,000 c.f.s. required a rising stage of 52.4 ft. on the Red River Landing gage in 1921 and a rising stage of 51.7 ft. in 1950. This same discharge was passed in 1950 on a falling stage of 53.6 ft.

A flood discharge of 1,300,000 c.f.s. was passed on a rising stage of 48.8 ft. in 1912 and 47.8 ft. in 1950. It was passed on a falling stage of 52.5 ft. in 1912 and 52.4 ft. in 1950.

A discharge of 1,000,000 c.f.s. was passed in 1892 on a rising stage of 40 ft., and on a rising stage of 39.4 ft. in 1950. In 1893, a discharge of 1,000,000 c.f.s. was passed on a falling stage of 43.1 ft., and the same discharge was passed on a falling stage of 45.8 ft. in 1950. A discharge of 1,000,000 c.f.s. occurs at or slightly below bankfull stage.

A discharge of 700,000 c.f.s., well below bankfull stage, was passed in 1882 on a rising stage of 31.2 ft. and on a rising stage of 31.8 ft. in 1950. The same discharge was passed in 1882 on a falling stage of 33.3 ft., and in 1950 on a falling stage of 35.5 ft.

A discharge of 500,000 c.f.s. was passed in 1885 on a rising stage of 22 ft., and in 1949 on a rising stage of 23.3 ft. In 1882 it required a falling stage of 26.0 ft. to pass a discharge of 500,000 c.f.s., and a falling stage of 27.0 in 1950.

The above data, together with additional data shown in Appendix C of this report, indicate that the discharge capacity of the Mississippi River at Red River Landing is now approximately the same as that shown for earlier comparable periods of record.

A slight trend towards deterioration of Mississippi River cross-sectional areas in the reach below Old River, due to increased flow from the Mississippi River toward the Atchafalaya, shown under "Old River Flow" on page 20, and under "Analysis of Problem, Flood Control," page 27, should have resulted in some loss of discharge in this reach for a given stage. However, it should be noted that, in 1938, extensive dredging was performed in the Mississippi River near Hog Point and 7,210,000 cubic yards of material were removed to make a more suitable alignment of the channel in this reach of river. It is probable that this improvement dredging, together with normal navigation dredging of the Smithland crossing, has provided a more efficient hydraulic channel. Continued loss in cross-sectional areas in the Mississippi River below Old River, however, must ultimately result in less discharge for a given stage and a corresponding increase in discharge through Old River for the same stage.

Reservoirs

A number of reservoirs have been constructed in the watershed of the Mississippi and Red Rivers; others are under construction, and a number of additional reservoirs are authorized. The completion and operation of all authorized reservoirs in these basins should reduce the variation between high- and low-water flow in the latitude of Old River. This reduction, however, can only be obtained by increasing the duration of peak regulated stages which could be the stage at which the greatest enlargement in the Atchafalaya River occurs. It is believed that reservoir regulation of flood flow in these watersheds will have a negligible effect on the enlargement of the Old and Atchafalaya Rivers.

Sill Dams

The effectiveness of the sill dams placed in the Atchafalaya River is discussed in detail in Appendices A, B, and C, accompanying this report. These discussions bring out the fact that during the life of Sill Dam No. 1 the cross-sectional area over the sill varied about 12,000 sq. ft. at bankfull stage and about 8,000 sq. ft. at low-water stage. This amount of variation indicates that the dam was not completely effective in maintaining a stable cross-sectional area at the structure. The Atchafalaya River cross-sectional areas below the dam enlarged during the life of the structure. The enlargement of the channel advanced downstream as the confining levees were progressively extended downstream. The construction of artificial levees undoubtedly influenced the river's rate of enlargement, and probably affects any restricting effect caused by the dam.

The discharge capacity of the Atchafalaya River at the time Dams Nos. 1 and 3 were constructed was less than 250,000 c.f.s. The present bankfull capacity of the Atchafalaya River is about 460,000 c.f.s. under 1950 conditions, and computations indicate that when project stages occur in the Red River backwater area, a discharge between 700,000 and 750,000 c.f.s. can be passed by Simmesport.

The Spillway Board, appointed by the Chief of Engineers 20 May 1926, in their report of 1927, entitled "Spillways on the Lower Mississippi River," H. D. No. 95, 70th Congress, 1st Session, stated that the construction of a gate structure in the great depth found in the Atchafalaya River would be a hazardous and extremely costly feat. Since 1927, the Atchafalaya River capacity at bankfull stages has increased from 320,000 c.f.s. to 460,000 c.f.s. The construction of any type of structure in the

Atchafalaya River at Simmesport or below will be a difficult and costly engineering undertaking and, if advanced very far into the future, can well become impracticable to construct.

All of man's works in the Old and Atchafalaya River Basins, commencing with the removal of rafts in the Atchafalaya and Red Rivers, except the construction of Sill Dams Nos. 1 and 3 and the underwater protection works at the Torras and Simmesport bridges, have tended to encourage the enlargement of the Old and Atchafalaya Rivers.

The only works of man in the latitude of Old River that now have a retarding influence on the enlargement of the Old and Atchafalaya Rivers are the Mississippi River bank stabilization works placed below and above the mouth of Old River in 1949 and 1950 and the navigation and improvement dredging work performed in 1935-38 on the Mississippi River near Smithland Landing, Louisiana.

Red River

The Atchafalaya River can now carry much more discharge and silt load than can be supplied by the Red River and its tributaries. The minor changes noted in the Red River reach included in this study are not sufficient to influence the development of the Atchafalaya River and are considered to be of a negative value in the over-all study.

CONCLUSIONS

Engineering and geological factual data presented in and with this report indicate that the Atchafalaya River will capture the Mississippi River unless prevented by man-made structures.

The rate at which the Atchafalaya River has advanced its accretions in Grand Lake, in the past, and the downstream advancement of the river channel from 1916 to 1950 indicate that with a continuation of this rate of advancement, an efficient single-river channel will be developed by 1985 or 1990. However, continued improvement in the hydraulic efficiency of the leveed channel of the Atchafalaya River and its unleveed Old River connection with the Mississippi River will permit additional floodwaters to pass into the unleveed basin. This increase in discharge should increase the rate of deposits of sediment which will confine larger flows within the channel. Confinement of larger flows within the channel should result in a progressive increase in the rate of advancement of the channel toward the sea. Increase in the flow now passing through the Atchafalaya Basin may also result in the deep water channel at the head of Stouts Pass moving upstream to a junction with a downstream advancement of the Atchafalaya River channel. There is some indication of this latter movement at the present time, and it is probable that an efficient channel through the basin above Morgan City will be developed earlier than the time shown by the average rate of advancement during the past.

The Atchafalaya River discharge for a stage of 40 feet at Simmesport increased 60,000 c.f.s. between 1892 and 1932. Between 1932 and 1950, for the same stage, the discharge capacity increased an additional 130,000 c.f.s., which is an average annual increase for the last 18 years of about 4.8 times the average rate of increase for the preceding 40-year period. If the increase in discharge capacity at Simmesport should continue to accelerate in the future at an average rate of 4.8 times the average rate of increase shown for period 1932 to 1950, the discharge capacity at Simmesport at a stage of 40 feet would be 1,064,000 c.f.s. by 1968. Inflow at the latitude of Old River required under existing conditions to develop a 40-foot stage at Simmesport and its equivalent stage of 46 feet at Red River Landing is about 1,700,000 c.f.s. When the Atchafalaya River is discharging 1,064,000 c.f.s. of this inflow, conditions in the Mississippi River below Old River would have deteriorated to such an extent that probably not more than 635,000 c.f.s. would then be passing down the main river. If this should occur, the usefulness of the Morganza and Bonnet Carre Floodways would be lost. Such a rapid reduction in the capacity of the Mississippi River is possible, but it is unlikely to occur.

The past rate of development of the Atchafalaya River channel indicates it will have an efficient channel by 1985 or 1990, and the rate of acceleration in increase of the river's discharge since 1932 indicates it will exceed 1,000,000 c.f.s. at a stage of 40 feet on the Simmesport gage by 1968. It is reasonable to assume that the channel will develop at a greater rate than that shown in the past. It is also reasonable to assume that the rate of acceleration of increase in discharge during the last 18 years will not continue for the next 18 years. It is likely, however, that these two conditions will result in the Atchafalaya River becoming the main or master stream below Old River somewhere between 1968 and 1985, probably around 1975.

The date on which the Atchafalaya River will become the master stream will, of course, be influenced by the frequency of the occurrence of a series of consecutive years having above-normal or below-normal rainfall in the drainage areas of the Red and Mississippi Rivers. Should we have a series of wet year cycles similar to those occurring in 1912-1916, 1927-1932, and 1940-45, the time required for the development of the Atchafalaya as the main river would be less than that required if a series of below-normal years should occur, such as those of 1906-1911, 1917-1921, and 1933-1936.

The time at which the Atchafalaya River would be so enlarged that it would be out of control will probably occur when it is discharging approximately 40 percent of the total discharge below the latitude of Old River. The rate of enlargement should be very rapid after the flow through the Atchafalaya River becomes 50 percent of the total flow passing the latitude of Old River. These latter two statements are based on experience and study of the deterioration of the Mississippi River channels when abandoned by natural and artificial cutoffs. (See Plates 18 and 19 for diversions of Mississippi River flow through chute of Island 8 and Brandywine Chute, and Plate B89, Appendix B.)

Plate 17 of this report indicates that the Atchafalaya River will be discharging 40 percent of the total flow at the latitude of Old River by 1960.

The heaviest deposit of silts has occurred between the upper end of Grand Lake and the lower end of the river levees. This has caused a marked deterioration in the discharge capacity of the floodway, as indicated by an increase in high-water elevations throughout the upper unleveed portion of the basin. Silt deposits tend to improve the main channel cross sections, but the increase in high-water elevations above Grand Lake shows this natural improvement is not sufficient to compensate for the deterioration in overbank flow conditions. Improvement dredging performed between 1932 and 1942 accomplished the purpose for which it was performed, but additional dredging is needed to arrest a trend toward higher flood flow lines in this reach. Improvement dredging is now needed in the Whiskey Bay channel, its extension to upper Grand River, and in the Blind Tensas Bayou channel. Improvement of the existing channel through this reach, however, would lower flood elevations between Krotz Springs and Atchafalaya, Louisiana, and cause further enlargement of the leveed channel above Whiskey Bay.

If the Atchafalaya River is to be prevented from enlarging to such an extent that it captures the Mississippi River, improvement dredging in the lower basin should await, if possible, the commencement of control or regulating works. It is necessary, however, that the floodway be made capable of passing a discharge of at least 1,000,000 c.f.s. and, as soon as practicable, the 1,500,000 c.f.s. required for the project flood, without overtopping the guide levees, which will probably make it mandatory that improvement dredging be initiated above Grand Lake within the next three years.

The advance of silt deposits through the lower end of Grand Lake and Six Mile Lake will ultimately require improvement dredging in this reach, as it is impracticable to raise the levees to higher grades. It is probable that dredging through the lake areas will be necessary when silt deposits fill Grand Lake and the upper reaches of Six Mile Lake to an elevation approximately equal to mean sea level. This condition will probably occur about 1960.

The Wax Lake Outlet is presently capable of discharging 270,000 c.f.s., its designed capacity, under project flood conditions. It would be advisable, however, to improve or enlarge this outlet to a discharge capacity of between 400,000 and 500,000 c.f.s., which should provide additional freeboard in the vicinity of Morgan City. Its discharge capacity should not be increased to such an extent that it causes deterioration in the Berwick Bay Outlet. Further engineering studies to determine the amount that can be discharged through Wax Lake without causing a deterioration in the Berwick Bay Outlet are necessary. The study should also anticipate a new channel from near Cypress Island to the present outlet after Grand Lake has been filled with sediment to approximately low-water stage. Additional dredging should be performed at the head of the Myette Point Cut to provide better entrance conditions through the cut for the discharge flowing through the west part of the floodway.

Under the project, some 600,000 c.f.s. is to pass into the basin through the Morganza Floodway. This discharge should be able to pass through the floodway area lying between the main channel and the east guide levee.

It is probable that it will be necessary to develop a channel from the mouth of Bayou Boutte upstream to upper Grand River so that the 600,000 c.f.s. to be discharged through the Morganza control structure can be carried through the floodway without overtopping the guide levees. The diversion of silt deposits that are now passing into the east floodway area between the lower end of the leveed channel and the east guide levee should be eliminated by the construction of dams or artificial levees immediately after the enlargement of the Whiskey Bay channel and its extension is completed.

The increased use of the Atchafalaya channel for navigation purposes will probably make it necessary, when authorized, to maintain a low-water channel through the Six Mile Lake area. The importance of the Atchafalaya River as a navigation route makes it necessary that any control or regulation works that may be constructed do not interfere with the use of the river for navigation purposes.

The project plan for the passage of 1,500,000 c.f.s. through the Atchafalaya Basin agrees closely with the plan proposed by the Spillway Board of 1927.

The distribution of flow below the latitude of Old River, in accordance with the adopted project plan, requires the maintenance of the present discharge capacity of the Mississippi River below Old River and the development and maintenance of a discharge capacity of 1,500,000 c.f.s. through the Atchafalaya Floodway. To depend upon nature to distribute flow in accordance with the project plan is hazardous and could ultimately result in the abandonment of the present flood control plan below Old River. The assurance of the ability to control the disposal of 3,000,000 c.f.s. of water below the latitude of Old River requires the ability to restrict the increase of the inflow capacity of the Atchafalaya River in the vicinity of Simmesport, Louisiana.

STRUCTURES AND COST

The directive of the Chief of Engineers does not specify that any data on regulating structures needed for the control of discharge through the Atchafalaya River, and their costs, be included in this report. The determination of the type, location, and cost of the structure or structures needed for the proper distribution of flood flow in the latitude of Old River requires thorough investigation and engineering study.

RECOMMENDATIONS

The Commission finds, on the basis of this detailed report, that the Atchafalaya River, if left alone, will capture the Mississippi. This view is supported by the unanimous findings of outstanding consultants who have been engaged in the study. How soon this will occur is not susceptible of precise determination. It would be unwise to remain unprepared to take prompt and effective steps to prevent such an occurrence. It would be equally unwise to undertake actual construction of preventive works without exhaustive study of the means of preventing this diversion. Because it will take some years to construct adequate control works and because delay may permit the situation to deteriorate so that construction of such works will become extremely difficult or impracticable, the Commission recommends:

(1) That the collection of hydraulic and hydrological information be continued;

(2) That detailed design studies, including model experiments if necessary, for a suitable structure or structures be initiated;

(3) That these studies be prosecuted vigorously with a view of being prepared to initiate promptly construction if the situation require it; and

(4) That detailed plans and cost estimates be prepared as rapidly as possible.

In arriving at the above findings and recommendations, the members of the Commission also considered the report on Geological Investigation of the Atchafalaya Basin and the Problem of Mississippi River Diversion prepared for the Commission, April 1952, by the Waterways Experiment Station under the general supervision of Harold N. Fisk, Ph. D., Consultant.

I, ROY D. McCARTY, Lt. Colonel, CE, the duly appointed Secretary of the Mississippi River Commission, certify that the above findings and recommendations were prepared by the Mississippi River Commission in executive session and unanimously approved on 23 April 1952 by all members present, Brigadier General Don G. Shingler and Colonel Ernest Graves (retired), being absent through unavoidable circumstances.

Roy D. McCarty

ROY D. McCARTY
Lt. Colonel, CE
Secretary, Mississippi River
Commission

APPENDIX A

INTERIM REPORT OF GEOLOGICAL INVESTIGATION

PREPARED BY

WATERWAYS EXPERIMENT STATION

FOR

MISSISSIPPI RIVER COMMISSION

CORPS OF ENGINEERS, U. S. ARMY

VICKSBURG, MISSISSIPPI

CONTENTS

CONTENTS

List of Figures

APPENDIX A

INTERIM REPORT OF GEOLOGICAL INVESTIGATION

PART I: INTRODUCTION

Purpose

The objectives of the Atchafalaya River study are: (a) to determine whether, if left alone, the entire flow of the Mississippi River will be diverted down the now-enlarging Atchafalaya River and, if so, to estimate the approximate date of this diversion; (b) to determine the effects of continued increase in Atchafalaya River flow on the Atchafalaya Basin and the Mississippi River below the point of diversion; and (c) to recommend steps for the control, or prevention, of diversion of the Mississippi into the Atchafalaya River. The purpose of the geological study is to investigate all phases of the problem wherein geology may be an important factor. The purpose of the present report is to summarize the progress of the geological investigations made to date.*

Scope of Geological Investigation

The above objectives involve the following considerations: (a) the sequence of events in the evolution of the Atchafalaya Basin and the origin and development of the Atchafalaya River; (b) composition of the bed and banks of Atchafalaya and Old Rivers and its influence on channel characteristics and development; (c) the influence of the growth of the Atchafalaya delta on the rate of diversion; (d) comparison of the stages of development of the Atchafalaya River with those known to have accompanied major diversions of the Mississippi in the geologically recent past; (e) an evaluation of the factors which influence diversions; and (f) correlation of engineering studies with geological information.

Scope of Interim Geological Report

The time available for preparation of the interim report was not sufficient for the complete realization of any of these objectives. Sufficient information has been obtained, however, to permit preliminary statements concerning the factors listed above. The broader outlines of the development of the Atchafalaya Basin and the origin of the Atchafalaya River have been established, and the composition of the bed and banks of the leveed sections of the river delineated in some detail. Prehistoric limits of Grand Lake have been traced, and the growth of the Atchafalaya delta and its possible effects on diversion outlined. The sequence of events leading to former major diversions of the Lower Mississippi River has been established firmly enough to permit a comparison with the present condition of the Atchafalaya River and prediction of probable future trends. The factors considered most important to river diversion have been listed and partially evaluated.

Studies Necessary to Complete the Project

A summary of the studies necessary to realize fully the objectives outlined above will clarify the present status of the investigation.

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* Authorization for the project and acknowledgements are contained in the main report, to which this is an appendix, prepared by the Mississippi River Commission.

Numerous local physiographic details in the upper part of the Atchafalaya Basin remain to be determined. A comprehensive study should be made of the development of the lower end of the Atchafalaya Basin including the sequence of alluviation. When this has been established, it should be possible to determine the extent to which this part of the basin has been affected by regional subsidence. In addition, a study of the lowlands south of the basin should be completed and the reason for localization of the Berwick Bay crossing of the natural levees of Bayou Teche investigated.

A careful evaluation of artificial influences, such as Carr Point Cutoff, dredging of the lower Atchafalaya channel, and Wax Lake Outlet, should be made to ascertain their effect on possible diversion of the Mississippi River.

Investigation of grain size and mineralogical character of Atchafalaya delta samples should be carried to completion and correlated with suspended-load and bed-load samples from the Atchafalaya, Red, and Mississippi Rivers. The purpose of these studies is to show principal sources of sediment, changes in source of sediment, and changes in carrying capacity of the Atchafalaya River.

Studies should be made of most major diversions of the Mississippi River and the distributary channels in both ancient and modern deltas, in order to develop criteria for recognition of the factors which affect channel enlargement, channel deterioration, and the mechanics of river diversion. In connection with these studies, the character, shape, and thickness of abandoned distributary fillings in the Mississippi River deltaic plain should be established by borings and physiographic studies.

The effects of continued increase of Atchafalaya discharge on the Atchafalaya Basin and the Mississippi River below the point of diversion should be furthur investigated.

It is estimated that 50 borings will be necessary to complete the project.

Sources of Information and Study Methods

Aerial photographs were one of the most important sources of information used in developing the geologic history of the Atchafalaya Basin and in delineating its physiographic features. Details were verified by borings at critical points. The aerial photographs available covered practically all the Atchafalaya Basin and were taken during the period 1931-49. It was found that the early aerial photographs, though ordinarily of inferior quality, were the most useful. They preserved the relict drainage and old meander scars much better than those taken after the Atchafalaya guide levees had been constructed and former drainage patterns obscured. Consequently, photographs made in 1931 were used wherever possible in tracing the physiography of the basin.

One hundred and twenty-five borings were made specifically for this study, including 19 undisturbed sample borings put down in the Atchafalaya delta to ascertain the character of materials forming the fill. A large number of logs of borings were available from other sources. Many of these were used in the preparation of this report; others were received too late to be included. The source, type and approximate number of borings available, other than the 125 project borings, are listed below.

Class A Borings (deep and carefully logged)

New Orleans District and Waterways Experiment Station . . .	350
Louisiana State Highway Department.	150
Railroad and pipeline companies, water wells, etc.	50
	550

Class B Borings (shallow and/or poorly logged)

New Orleans District	1000
Seismic shot points (made for geophysical exploration)	2000
	3000

Early Government land plats (1808-31) of portions of the Atchafalaya Basin proved most helpful in the study. U. S. Coast and Geodetic Survey charts were available, showing soundings in Atchafalaya Bay as early as 1858. Hydrographic surveys of the Atchafalaya River, made by the Mississippi River Commission in 1881, 1904, and 1916, and later ~~hydrographic and bank-line surveys made by the New Orleans~~ District, were examined. Soils maps of St. Martin and Iberia Parishes prepared by the U. S. Bureau of Soils were available. Quadrangles, scale 1:62,500, cover most of the Atchafalaya Basin and were used wherever possible as base maps. Rapid shifting of the Atchafalaya River bank line in some areas and the phenomenal growth of the Atchafalaya delta have made many of these quadrangles obsolete. The latest bank-line surveys of the Atchafalaya River and of the Grand Lake area, made in 1950 by the New Orleans District, have been added to the base maps.

All available published information concerning the Atchafalaya Basin and unpublished reports in the files of the Mississippi River Commission were examined for data relating to geologic aspects of the problem. A brief digest of the published literature is contained in the following part.

PART II: SURVEY OF PUBLISHED LITERATURE

The Atchafalaya River has been discussed in several geologic reports and has been the subject of a considerable number of engineering investigations. An exhaustive review of this rather extensive literature would not contribute materially to the purposes of this study. However, some consideration of the more pertinent contributions is necessary in order to place the present study in proper perspective.

The mouth of the Red River and the head of the Atchafalaya River were discovered by De Soto in 1542. According to Elliott,[4*] a map dated 1578 drawn by Monk Ptolemy, who accompanied the expedition, is said to show conclusively that the Atchafalaya then, as now, served as an outlet for the Mississippi River. It is thus reasonably certain that the problem of eventual capture of the Mississippi by the Atchafalaya is one of long standing, having originated at least 400 years ago. Furthermore, no substantial changes appear to have occurred in the upper portion of the Atchafalaya channel between 1542 and 1831.

The idea that the Red River once entered the Gulf of Mexico directly, without first joining the Mississippi, seems to have gained considerable popularity in the early part of the 19th century. The exact course which the Red River was supposed to have followed was usually not stated. Ellicott[3] seems to have been the first to suggest that the Atchafalaya may have been a former channel of the Red River. About the same time the view seems to have been held that the Mississippi formerly followed the channel of the Atchafalaya to the Gulf. This view was opposed by Schultz[19] who pointed out that the Atchafalaya channel was much too small ever to have carried the entire flow of the Mississippi. Fairly detailed reviews of these early speculations may be found in Bulletins 10 and 18 of the Louisiana Geological Survey.[5,6]

The stability of the lower Red and upper Atchafalaya courses during the period 1542 to 1831 is confirmed in a book published in 1816 by William Darby,[1] in which it is stated that early in the 19th century the Atchafalaya River debouched from the Mississippi about three miles below the mouth of the Red River. Darby, who seems to have been an acute and accurate observer, had much to say about the Atchafalaya, including the almost clairvoyant statement that some day the Government of the United States would be impressed with the importance of the Atchafalaya headwaters. In fact, he may justly be considered the founder of alluvial geology, for many of his conclusions are drawn from the same lines of evidence as those used in this study, size of channel as compared with the present volume of flow, color of soils, etc. He describes in some detail the raft of logs which choked the upper reaches of the Atchafalaya and states that at the time of publication of the book the raft had been in existence for only about 38 years. If so, then prior to 1778 the river must have been free from this obstruction. He believed that the Atchafalaya was at some remote period the continuation of the Red River, a view to which he seems to have been inclined partly because of the occurrence of red soils in the Atchafalaya Basin. This view has been held by others both before and after Darby, but is probably erroneous. Segments of former Red River courses do occur at various points in the Atchafalaya Basin, but are not at present occupied by the Atchafalaya River.

The year 1831 marked the completion of Shreve's Cutoff across the neck of Turnbull Bend. The changes brought about by this cutoff are discussed by Elliott and reported in detail in the report of the Chief of Engineers for 1880. The effects of this cutoff are discussed elsewhere in this report; therefore, it is mentioned here only to point out that by interposing the hydraulically comparatively inefficient channel of Old River between the Mississippi River and the head of the Atchafalaya,

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* Superior numbers refer to sources listed in the selected bibliography at the end of this appendix.

Shreve's Cutoff must have altered considerably the regimen of the Atchafalaya.

The first mention in an official document of the possibility of eventual capture of the Mississippi River by the Atchafalaya, or some other outlet bayou, occurs in a report by Charles Ellet, dated 1852.[2] However, his treatment of the question indicates that it was even then one of long standing and of great interest to the inhabitants of the Lower Mississippi Valley. Ellet did not share the apprehensions of those who believed that the Atchafalaya would eventually become the main channel of the Mississippi. On the contrary, he believed that the Atchafalaya channel was deteriorating, as may well have been true at that time, and doubted that it could be made to carry an increased portion of Mississippi River floodwaters without a great amount of dredging. At that time, the extreme high-water discharge of the Atchafalaya appears to have been only about 13 percent of that of the Mississippi. From a geological point of view, Ellet's report is of interest for its theory of origin of the Atchafalaya River. He rejected the view that the Atchafalaya is the continuation of the Red River on the grounds that the Atchafalaya channel was then too small to have ever accommodated the entire discharge of the Red, which he estimated to be about twice that of the Atchafalaya. He then advanced the theory that the Red River originally followed the present channel of Bayou Teche, and that the Ouachita (Washita) River followed the present course of the Atchafalaya. The gradual approach of opposite bends caused the Ouachita and Mississippi courses to intersect in the vicinity of Old River, leaving the lower courses of the former Ouachita as the present Atchafalaya. Subsequently, the Red River crevassed its natural levees to form its present junction with the Mississippi and Atchafalaya. In support of his view he pointed out that the discharges of the Ouachita and Atchafalaya Rivers were then closely comparable.

The work of the so-called "delta survey" was largely accomplished between the years 1857 and 1861.[13] The view is expressed in this report that the beds of the Lower Mississippi River and distributaries are not composed of alluvial deposits, but of a thick bed of hard clay laid down during a geologic period antedating the present river. This view exercised considerable influence on schemes for flood control for some time, but has long been known to be completely erroneous. It is interesting to note that "the tough clay bar that projects obliquely across the efflux of the Atchafalaya from Old River 35 feet below the bank, and about 15 feet below the level of the gulf" actually exists, but forms the upper banks rather than the bed of the river as Humphreys and Abbot apparently thought (Plate A10). Oddly enough, Humphreys and Abbot's belief that "the Atchafalaya was a mere valley drain, discharging clear water, until the Mississippi, by eroding its own bank, converted it into a waste-weir, when, becoming a muddy stream of increasing discharge, the Atchafalaya began to raise its banks" is with only comparatively minor modifications amply substantiated by the findings of the present study.

The period between the delta survey and the early work of the Louisiana Geological Survey in the Atchafalaya Basin was marked by the removal of the raft in 1861 and the extension of levees down both banks of the Atchafalaya. No important geologic work seems to have been accomplished during this time.

In 1931, Howe and Moresi[10] published a geologic study of Iberia Parish. The former occupation of the present Bayou Teche by both the Mississippi and Red Rivers was clearly demonstrated. In addition, this publication contains an annotated bibliography of 224 titles, a number of which deal with the geology of the Atchafalaya Basin.

The same authors described the geology of Lafayette and St. Martin Parishes in a bulletin published in 1933.[11] This publication contains a brief account of the Atchafalaya Basin, but does not trace the drainage development in a manner useful to the present study.

A further bulletin of the Louisiana Geological Survey, published in 1938,[12] describes the geology of Iberville and Ascension Parishes and discusses the Atchafalaya Basin in some detail. It was pointed out that the basin occupies a depression formed partly by regional subsidence and partly by alluviation along the former Bayou Teche course of the Mississippi on the west and the former Bayou Lafourche course of the Mississippi on the east. Origin of the Atchafalaya River was attributed to crevassing of the natural levees of the Mississippi River. In the last section of the bulletin, Kniffen discussed the relative ages of the Indian mounds occurring along various natural levees of the region. The archaeological evidence of age of these mounds was found to be in good agreement with the geological evidence of age of the natural levees. This paper marks a long step forward in knowledge of the Atchafalaya Basin.

A paper by R. J. Russell,[16] published in 1939, presents very clearly the criteria used in working out the drainage history of alluvial regions. The deep, wide holes present in the bends of the Atchafalaya River and the narrow, shallow crossings in reaches were considered to be a reflection of the increased discharge of the channel during recent years. It was concluded that when stability is attained the reaches will become wider and the holes shallower.

Knowledge of the Atchafalaya Basin was considerably advanced by another publication by Russell in 1940.[17] This paper presented for the first time a reasonably complete account of the evolution and history of the Mississippi delta. The former Teche, Plaquemine, and Lafourche courses of the Mississippi River were discussed in some detail.

Fisk gives brief descriptions of the Atchafalaya Basin and the Teche, Atchafalaya, Grosse Tete, and Lafourche natural levee ridges in his investigation of the geology of the alluvial valley of the Mississippi River.[7] Rather detailed descriptions of the Lafourche, Teche, Cocodrie, Maringouin, and Bayou La Rose deltas, which are located in the southern portion of the Atchafalaya Basin, are also contained in this publication.

In a letter dated 9 July 1945 to the President, Mississippi River Commission, subject, "Geological aspects of increased Atchafalaya River flow," H. N. Fisk stated that there is a definite possibility that the Mississippi River will be captured by the Atchafalaya. This letter contains a rather detailed analysis of the processes leading to major diversions of the Mississippi River channel. It was pointed out that from a geological point of view a river diversion takes place in two stages. The first covers a long period of time during which a channel is established by continued diversion of high-water flow. The second begins with the diversion of low-water flow into the new channel, and covers a short period of time during which the entire low-water flow is concentrated in the new channel, and the old channel becomes filled with silt and sand. Each diversion reached completion because of a gradient advantage and the persistence of flow through the point of bifurcation. The speed of each diversion was apparently determined by the erodibility of the bed and bank materials.

By reason of analogy with the diversion of the Mississippi River from its former Bayou Lafourche course to its present channel, it was stated that a new diversion channel is extended seaward by the building out of a distributary system. In the initial stage of a diversion, scouring is limited to the point of crevassing. Sediments derived from this action overload the stream and cause it to deposit its load when the velocity is checked at the level of the adjacent lowland. High-water occupation of the crevasse channel results in gradual lengthening of the course along selected channels. This process continues until the zone of steep gradients is gradually flattened and forced seaward. The lowering of slope resulting from seaward extension of the channel is accompanied by a progressive downstream deepening and widening of the channel. Deepening of the channel is in part brought about by the formation of natural levees which confine the discharge and promote scouring. Complete low-water diversion is reached only after the river develops a better channel than the one previously occupied. After the main low-water flow has been concentrated in the diversion channel, abandonment of the former channel takes place very quickly.

It was concluded that although the Atchafalaya seems still to be in the early, long-continued stage of development, channel enlargement may be expected to be a more rapid process in the case of the Atchafalaya River than the former Bayou Lafourche diversion, where the fine-grained topstratum is much thicker. Furthermore, engineering works along the Atchafalaya have accelerated the enlarging process. An increase in the rate of channel enlargement was held to be a possibility although the danger of diversion was not believed to be imminent. The present geologic investigation of the Atchafalaya Basin is, in some measure, an extension and amplification of this earlier study.

A book entitled "Rebellious River"[14] contains an interesting historical account of flood control engineering in the Lower Mississippi Valley. It also contains a good deal of outspoken criticism of the Corps of Engineers and not a few of the author's personal opinions. The Atchafalaya Basin is treated in considerable detail. Closure of Old River is strongly advocated because capture of the Mississippi by the Atchafalaya River is considered to be imminent. This book contains very little new information of value and makes only cursory references to geological matters. Some of these are rather curious; for example, the statement that although Humphreys and Abbot's views concerning the geological age of the hard clay stratum thought to form the bed of the Mississippi River and distributaries are probably wrong, this clay stratum exists nevertheless, and is formed by the settlement of clay particles to the bottom while the coarser materials are carried downstream. Incidentally, it may be remarked that the idea of a persistent clay stratum seems to die very hard indeed, for in a modified form it also appears to be favored by Odom.[15] Despite some shortcomings, this book constitutes a readable and stimulating account of flood control problems in the Lower Mississippi Valley.

This section would be incomplete without mention of two papers which, although primarily engineering in character, deal with basic principles governing the behavior of alluvial rivers, and exemplify the two opposing views that have long been held concerning the ultimate effect of diversions, or outlets, on the main channel of the river. The first was published by E. F. Salisbury, Chief Engineer of the Louisiana and Arkansas Railway, in 1937.[18] He concludes, from a study of the records of selected gages on the Mississippi and Atchafalaya Rivers, that the behavior of the Mississippi River below the head of Old River has been in accordance with hydraulic theory; i.e., the Mississippi has steepened its slope by deposition of material below the point of diversion as its volume decreased. The Atchafalaya River, on the other hand, has acted in accordance with hydraulic theory by flattening its slope by erosion of its bed as the volume progressively increased. Salisbury states that the Atchafalaya appears to be the natural course for the Mississippi River to follow, but inasmuch as diversion did not take place under natural conditions, before the advent of engineering works, he concludes that the shorter route must be blocked because of the manner in which the river treats the silt load. Thus an increase in head is necessary in order to increase the discharge.

The second paper is by L. M. Odom and was published in 1950.[15] Odom contends that discharge measurements made prior to 1913 are too inaccurate to be used in a study of the type conducted by Salisbury, and that if these measurements are discounted there is no evidence of deterioration of the Mississippi River channel below Red River Landing. He believes that the bar below the head of Old River may have been formed as the result of local conditions in the channel and thus does not constitute sufficient proof of deterioration of the entire channel below this point. The apparent lack of deposition in the Mississippi channel below Old River is explained by the suggestion that the Atchafalaya River may divert a disproportionately high percentage of the bed load of the Mississippi. The results of model tests of sediment transportation in bifurcating channels are cited in defense of this view.

In a discussion of Odom's paper, Halsey[9] points out that a comparison of the

Simmesport and Krotz Springs gages indicates that the increase in channel capacity in the vicinity of Krotz Springs is only about 50 percent of that shown at Simmesport. This is interpreted to mean that the Krotz Springs area is proving a serious deterrent to the over-all enlargement of the stream. Assuming a continued rate of increase in discharge capacity comparable to that of 1935 to 1949, it is stated that 180 years will be required for the Atchafalaya to capture the Mississippi River.

To summarize, geological studies of the Atchafalaya Basin conducted prior to the present investigation were of a rather general character, and while sufficient to establish the broader outlines of the geological history of the region, lack the detailed information concerning the composition of the bed and banks necessary for engineering purposes. Furthermore, engineering opinion seems to have been somewhat divided concerning the probable future behavior of the Atchafalaya River and the consequences of its possible capture of the Mississippi River.

PART III: ATCHAFALAYA RIVER AND ITS BASIN

The Atchafalaya River is the principal distributary of the Mississippi River. For the past decade it has carried a discharge exceeded in the United States by few other rivers. Virtually all of this discharge is derived from the Mississippi and from the Red River which joins the Atchafalaya River near its head. Records show that there has been an average annual increase in Atchafalaya flow, and the increase is due almost entirely to the progressively greater volume of Mississippi River water being diverted into this distributary.

The Atchafalaya River flows through a low, well-defined basin. The low elevation of the basin as compared with adjacent areas offers a gradient advantage to waters flowing from the Mississippi-Atchafalaya junction to the Gulf of Mexico. This gradient advantage is one of the principal reasons for the progressive increase in amount of Mississippi River water which is diverted into the Atchafalaya River.

The Atchafalaya Basin

The Atchafalaya Basin (Fig. 1) is a lowland portion of the Mississippi Alluvial Valley, bounded on all sides by natural levee ridges. The basin extends in a general north-south direction from the latitude of Old River and Bayou des Glaises to the southern end of Six Mile Lake, and east-west from the Mississippi River and Bayou Lafourche to the vicinity of Bayou Teche. It is over 100 miles long, and has an average width of 30 miles. The slope of the basin surface is gently seaward, from about 40 ft. m.s.l. near its northern limits to the latitude of Krotz Springs, Louisiana, where the average elevation is 10 ft. m.s.l. South of Krotz Springs, the basin is extremely low, and is under water for much of the year. Permanent dry land areas in this southern portion are restricted to natural levee ridges.

Natural levee ridges

The most conspicuous physiographic elements of the basin are natural levee ridges. Natural levees are built along both sides of streams where sediment is dropped during periodic overbank stages, and rise above the general level of the basin surface as low asymmetric ridges. The ridges reflect the size and pattern of the streams which produced them, streams not necessarily those now flowing along the ridges and from which the ridges take their names.

The most prominent ridges are those bounding the basin (Fig. 1). The Teche ridge forms the western and southern basin boundaries and is occupied by several streams (parts of Bayou Jack, Rouge, Negro Foot, Wauksha, Courtableau, all of Bayou Teche, parts of Lower Atchafalaya River, Berwick Bay, Bayous Boeuf, L'Ourse, and Black), the longest of which is Bayou Teche. The basin is bounded on the north by natural levee ridges along Bayou des Glaises, the Atchafalaya River from its head to Simmesport, and Lower Old River. The eastern, or northeastern, boundary is formed by natural levees along the Mississippi River from the head of Old River to Donaldsonville and thence along Bayou Lafourche from Donaldsonville to Houma. At Houma, the Lafourche ridge overlaps the Teche ridge, completing the encompassment of the basin. Both the Teche and Lafourche ridges break up into a number of minor ridges near their distal ends in a manner analogous to the present Mississippi delta.

The ridge along which the Atchafalaya River flows extends down the center of the basin from Simmesport to Krotz Springs. Farther south it gradually diminishes in height until it disappears a few miles north of Grand Lake. The Grosse Tete ridge is roughly parallel to the Atchafalaya ridge from Morganza to the latitude of Plaquemine also gradually disappearing southward.

Between ridges, the basin surface has little relief. A few low arcuate features having the dimensions of the Red and Mississippi meander loops rise above the general level, but these cannot be followed as uninterrupted ridges.

Drainage

The Atchafalaya River does not drain the northern part of the basin. Streams in the inter-ridge areas are not integrated into any efficient drainage system, but wander freely in complex networks over the area, emptying eventually into lakes in the southern part of the basin. A few of the larger streams, such as Bayou Courtableau were, under natural conditions, tributaries of the Atchafalaya River, and a few, such as Alabama Bayou, were distributaries of the river, but their connections have been severed by the artificial river levees built along the Atchafalaya River. Guide levees which mark the boundaries of the Atchafalaya and Morganza Floodways are located five or six miles from the river on either side, and have served to interrupt natural drainage in inter-ridge areas. The net effect of the construction of these two levee systems was to channel drainage southward beyond their ends into the lake areas in the southern end of the basin.

Lake areas

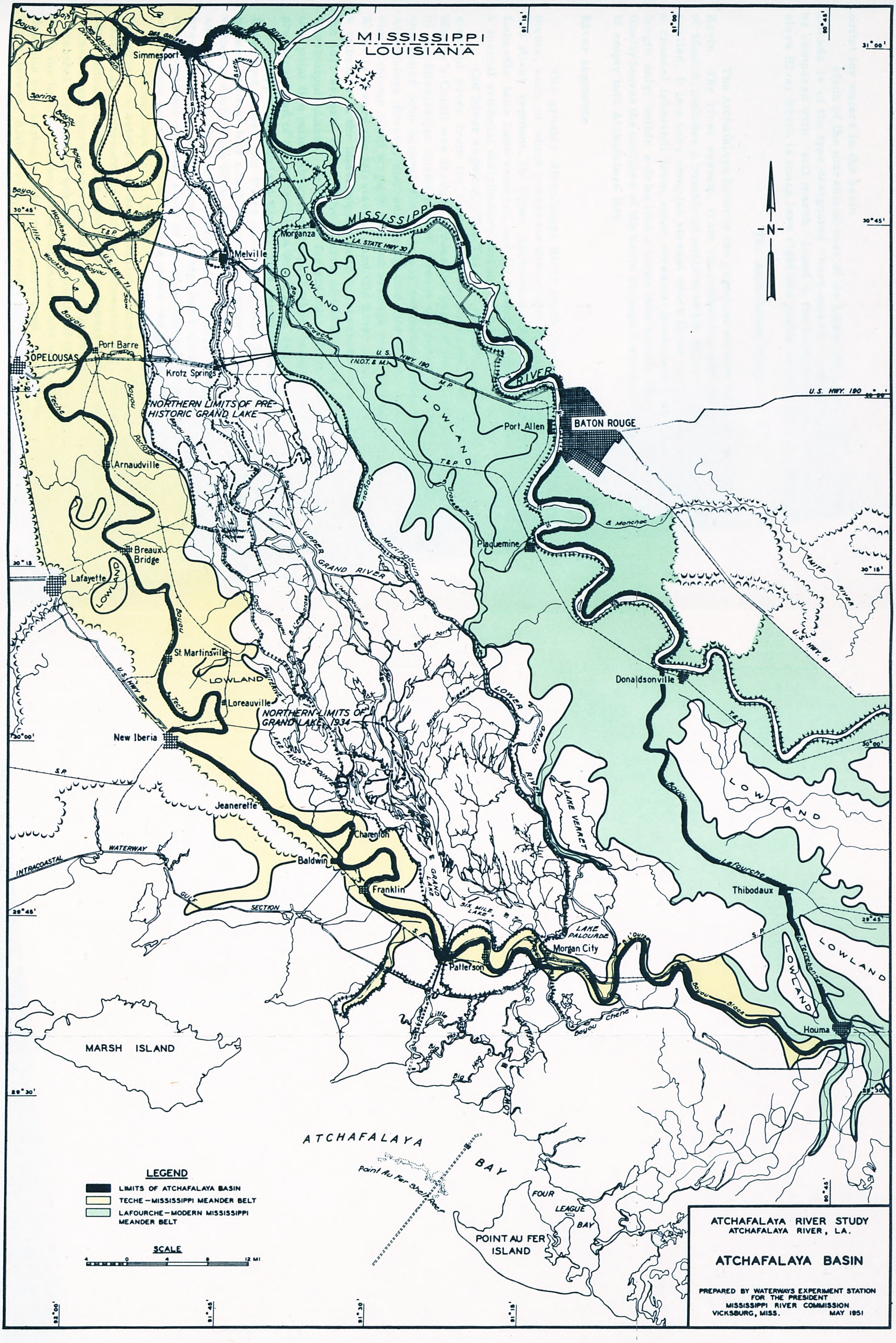
The low southern part of the Atchafalaya Basin contains a system of shallow lakes consisting of the centrally located Grand Lake-Six Mile Lake water body, Lake Fausse Point on the west, and Flat Lake and Lake Palourde on the east. Lake Verret lies within the basin to the north of Lake Palourde. Approximately 150 square miles of the basin is covered by lakes.

Drainage between adjacent lakes is accomplished either through direct connection or by a network of swamp streams. Drainage from Flat Lake into Lake Palourde has been prevented by the artificial levees of the Morganza Floodway. Waters from the lakes leave the basin through a number of outlets across the Teche ridge. Most of these outlets eventually enter Lower Atchafalaya River. The area between the lakes is very similar to that of the Mississippi deltaic plain. It is swampy and covered by water for much of the year.

Lowlands South of Atchafalaya Basin

On the south side of the Teche ridge is a strip of marshland 15 to 25 miles wide, a part of which extends across coastal Louisiana. The Lower Atchafalaya River crosses these marshlands to conduct the drainage of the Atchafalaya Basin to Atchafalaya Bay, an arm of the Gulf of Mexico.

The marshlands are studded with lakes. The prominent lakes of the region are Wax Lake, Bateman Lake, Sweet Bay Lake, Lake Decade, and Four League Bay, separated by intervening marshlands across which flows a network of shallow, sluggish streams. Water from most of these lakes finds its way into Lower Atchafalaya River where it joins the drainage from the Atchafalaya Basin. The Lower Atchafalaya River has a deep channel and carries a considerable volume of water from its source near Patterson to Berwick Bay, thence to Bateman Lake, Sweet Bay Lake, and Atchafalaya Bay. Some drainage water is added to the Lower Atchafalaya from marshlands and lakes east and west of it. Waters also flow into Lake Decade and Four League Bay and directly into Atchafalaya Bay. Wax Lake, west of Lower Atchafalaya River, is connected to Six Mile Lake within the Atchafalaya Basin by an artificially constructed channel across the Teche ridge. Wax Lake Outlet and Lower Atchafalaya River are at the southern openings of the Morganza-Atchafalaya Floodway system of guide levees. Bayou Chene which drains Lake Palourde through Bayou Black is a minor


MISSISSIPPI
LOUISIANA
Simmesport
Morganza
LA. STATE HWY 30
MISSISSIPPI
RIVER
Melville
LOWLAND
OPELOUSAS
Port Barre
Krotz Springs
U.S. HWY. 190
NORTHERN LIMITS OF PRE-HISTORIC GRAND LAKE
BATON ROUGE
Port Allen
Arnaudville
Breaux Bridge
Plaquemine
UPPER GRAND RIVER
Lafayette
St. Martinsville
Loreauville
LOWER GRAND RIVER
Donaldsonville
NORTHERN LIMITS OF GRAND LAKE, 1934
New Iberia
LAKE FAUSSE POINTE
Jeanerette
LAKE VERRET
Charenton
Baldwin
INTRACOASTAL WATERWAY
Franklin
GULF SECTION
LAKE PALOURDE
Morgan City
Patterson
Thibodaux
Houma
Bayou Lafourche
Bayou Black
MARSH ISLAND
ATCHAFALAYA BAY
Point Au Fer Shell Reef
FOUR LEAGUE BAY
POINT AU FER ISLAND
AMITE RIVER
U.S. HWY. 61
LEGEND
LIMITS OF ATCHAFALAYA BASIN
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ATCHAFALAYA RIVER STUDY
ATCHAFALAYA RIVER, LA.
ATCHAFALAYA BASIN
PREPARED BY WATERWAYS EXPERIMENT STATION
FOR THE PRESIDENT
MISSISSIPPI RIVER COMMISSION
VICKSBURG, MISS. MAY 1951

FIGURE 1

outlet for waters in the basin.

Much of the marshland east of the Lower Atchafalaya River and north of Lake Decade is of the type designated "hard marsh," indicating that it is relatively firm as compared with "soft marsh" found in the immediate vicinity of the Lower Atchafalaya River which is much less rigid and yields easily under slight pressure.

The Atchafalaya River

The Atchafalaya River is the principal stream flowing through the Atchafalaya Basin. The river system, from its connection with its principal source to the Gulf of Mexico, includes a number of parts to which different geographic names have been applied. It is a very complex stream which flows partly in its own channel, partly in a channel inherited from other streams; possesses a single channel for part of its length only; builds a delta into a large lake system which lies along its course; and finally leaves the confines of the basin through a series of openings in the Teche ridge to empty into Atchafalaya Bay.

River segments

The greater Atchafalaya River lends itself to division into a number of segments, each of which possesses distinctive characteristics. These are: (a) Lower Old River segment, (b) Upper Atchafalaya River, (c) Atchafalaya delta, (d) Grand Lake-Six Mile Lake segment, and (e) Lower Atchafalaya River. Wax Lake Outlet is a special artificial distributary, not actually part of the river.

Old River segment. The Turnbull Island meander loop was used by the Mississippi River from the time of the earliest river records until 1831. In that year Shreve's Cutoff was dredged across the neck of the meander loop, and the main flow of the Mississippi finally passed through the cutoff. In time the lower branch of the abandoned loop became the principal connection between the Mississippi, Red, and Atchafalaya Rivers, and was designated Old River. Under certain conditions (i.e., simultaneous flood stage in Red and average stage in Mississippi), flow through Old River is toward the Mississippi, and Old River is actually part of the Red River and a tributary of the Mississippi. Such occurrences have become increasingly rare in the last several years. The course of Old River is closely controlled by the older Mississippi channel. It extends for six miles from its junction with the Mississippi to a point five miles above Simmesport where it joins the Red River to form the geographical head of the Atchafalaya River (Fig. 2).

Upper Atchafalaya River. This segment extends from the junction of the Red River and Lower Old River to Whiskey Bay Pilot Channel, a river distance of 58 miles. Through this reach the river occupies a single, well-integrated channel which varies in depth from 50 to 140 ft. The river is remarkably straight, having few meander loops such as characterize most alluvial valley streams. Most of the bends present are not meander loops, for they have shown no tendency to migrate or change their position. On both sides of the river natural levee ridges, upon which artificial levees have been constructed, rise above the general level of the Atchafalaya Basin.

Atchafalaya delta. South of the dredged Whiskey Bay Pilot Channel, the river comprises a network of small shallow streams extending to the present limits of Grand Lake, approximately 50 miles downstream. This low area represents an accumulation of Atchafalaya River deltaic deposits which have been gradually filling an ancestral and much larger Grand Lake. Figure 1 shows the maximum limits of this ancestral lake and the northernmost limits of the lake in 1934. A navigable channel from the head of Whiskey Bay Pilot Channel has been constructed across these deltaic deposits by dredging, cutoffs, and other means. Prior to the construction of artificial river levees, Alabama Bayou, 12 miles upstream from Whiskey Bay Pilot Channel,

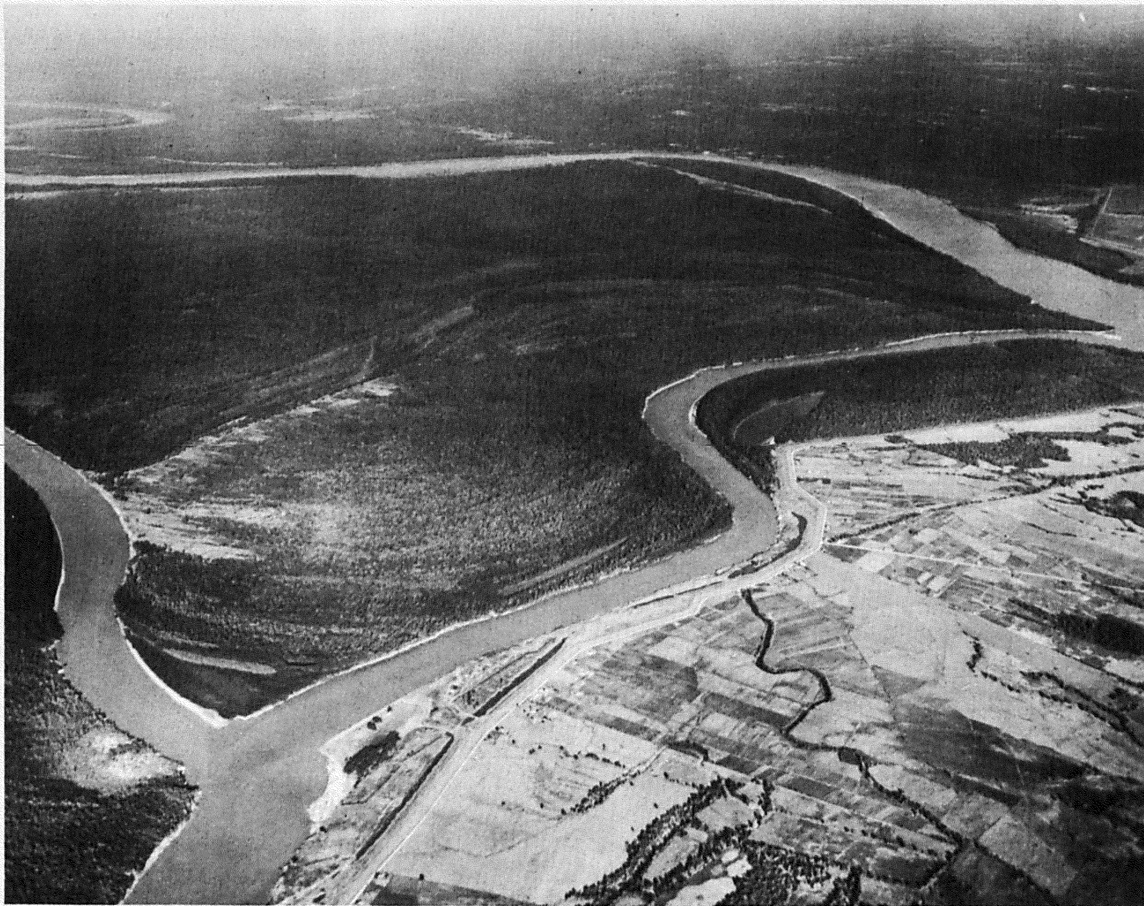

Figure 2. Confluence of Old, Red and Atchafalaya Rivers in lower left; Mississippi River in upper right

was the first distributary of the Atchafalaya River and may be considered as the head of the earliest recognizable Atchafalaya delta.

Grand Lake-Six Mile Lake segment. These two interconnected water bodies are the result of the impounding of water in the low southern end of the Atchafalaya Basin. Both lakes are threatened with extinction by the growth of the Atchafalaya delta. Recently both have become so shallow that navigation is limited to 5-ft. depths at low-water stage.

Lower Atchafalaya River segment. The natural outlet for the Atchafalaya Basin drainage system is through Lower Atchafalaya River. Prior to 1941 part of the basin drainage entered a channel which connected Six Mile Lake with Bayou Teche near Patterson, and flowed eastward along Bayou Teche to Berwick Bay. This channel has been sealed off, however, and the main flow from the basin enters the Lower Atchafalaya River by way of Berwick Bay from Six Mile Lake through Stouts Pass, and from Flat Lake through Drews Pass. The river flows from Berwick Bay into Atchafalaya Bay and into the Gulf of Mexico across approximately 20 miles of soft marsh coastal lowlands. Water also drains from Lake Palourde into Bayou Boeuf, which is connected to Bayou Shaffer through Bayou Chene. The flow continues through Bayou Shaffer and thence into the Lower Atchafalaya River at Sweet Bay Lake. Normal river scour makes navigation of small craft possible in Lower Atchafalaya River, but a channel is dredged in places to permit ocean-going traffic. The channel is as much as 160 ft. deep in places.

Wax Lake Outlet. A second major outlet for waters of the Atchafalaya Basin has been opened artificially through Wax Lake, connecting Six Mile Lake to Atchafalaya Bay. This is known as Wax Lake Outlet.

Origin and Development of the Atchafalaya Basin

The Atchafalaya Basin was formed in comparatively recent times as a result of the growth and development of the alluvial valley of the Mississippi River, and represents the latest stages of a history of valley cutting and subsequent filling brought about by the advance and retreat of the continental ice sheets during the glacial epoch. Growth and advance of the ice sheets caused a lowering of sea level by several hundred feet, resulting in the entrenchment of a valley which attains some of its greatest depths below the portion of the Mississippi River Alluvial Valley known as the Atchafalaya Basin. Melting of the ice and subsequent rise in sea level brought about a reduction in stream gradients causing a gradual filling of the entrenched valley.

The deposits which fill the entrenched valley can be divided into two principal units: substratum and topstratum. Substratum deposits consist of coarse pervious materials that accumulated principally during the time when the sea was rising to its present level. Deposition was closely geared to the rising sea level, and the resultant progressive decrease in stream gradients. Coarse gravels were deposited in the bottom of the trench, with finer gravel and sand sizes deposited as sea level was approached. Topstratum deposits consist of finer alluvial materials, silty sand, silt, and clay in various combinations, which accumulated over the valley surface after sea level had reached essentially its present stand. These deposits are relatively impervious as compared with the substratum, and are unevenly disposed above substratum "clean" sands.

The grain size of topstratum deposits is related to the decreased sedimentary load transported by streams in the Mississippi Alluvial Valley as their gradients become adjusted to the present sea level position. Reduced stream gradients resulted in a reduction of the size and quantity of sediment transported, until eventually the load consisted mainly of suspended material and a relatively small bed load of sand. As this stage was reached, the rivers began to meander, and the Mississippi River and many of its tributaries became "poised" streams, showing no tendency to aggrade or degrade their channels. Topstratum in the Mississippi Alluvial Valley was deposited almost exclusively by poised, meandering streams.

The topstratum may be divided into natural levee, point-bar, abandoned channel, backswamp, and deltaic deposits according to environment of deposition. These are described in Part IV of this appendix. Details of the geologic history of the Mississippi River Alluvial Valley, and comprehensive descriptions of the various environments of alluvial deposition may be found in earlier reports.[7,8]

The Mississippi River changed the position of its meander belt several times after it became a meandering stream. Periodic overflow, natural levee construction, and meander growth caused the river to be lengthened and the part of the alluvial valley adjacent to the river to be raised. This set the scene for divergence of the river, as potentially shorter paths to the Gulf of Mexico became available. Wherever and whenever the river could escape from the confines of its natural levees, it was diverted to a different part of the valley, taking advantage of the steeper gradient of the diversion course. The abandoned meander belt remained as an alluvial ridge, and in most cases a stream much smaller than the Mississippi occupied the old channel. The size of natural levees and meander loops and distinctive character of deposits make possible separation of abandoned Mississippi meander belts from those left by smaller alluvial valley streams such as the Red and Ouachita Rivers.

Knowledge of these factors in the behavior of alluvial valley streams has made it possible to understand the creation of the Atchafalaya Basin through the complete encirclement of its area by old Mississippi River natural levee ridges.

Details are lacking on the earliest of the abandoned Mississippi River courses which influenced the development of the Atchafalaya Basin. The first of the easily traceable courses is the Teche-Mississippi which forms the western and southern boundaries of the basin (Fig. 1). This course is now followed by a number of minor streams (page A9) which flow in the large arcuate meanders formed by the Mississippi. The Teche-Mississippi followed closely the western wall of the alluvial valley for much of its course. Near Franklin, it was prevented from continuing southward to the Gulf by what appears to have been an eastward extension of the valley wall in that sector. Borings show the presence south and east of Franklin of a buried ridge formed of older and more consolidated materials similar to those forming the present valley wall. This ridge evidently diverted the course of the Teche-Mississippi eastward and an extensive delta was built south and east of Houma.

The Mississippi River abandoned its Teche course along the western side of the alluvial valley in favor of a new course adjacent to its eastern valley wall. The new course extended from Marksville to Angola along what is now Bayou des Glaises, a portion of the Atchafalaya River and a segment which has been reworked by the present Mississippi and is now occupied by Lower Old River. Natural levees built along this part of the course form the northern boundary of the basin. South of Angola, the Mississippi occupied its present course to Donaldsonville, Louisiana. South of Donaldsonville, the river flowed in a channel now partially used by Bayou Lafourche, and established a delta in Lafourche and Terrebonne Parishes, south of Thibodaux. The delta-building left small diverging distributary ridges, built out into coastal marshlands, overlapping the deltaic ridges of the Teche course, and crossing them at nearly right angles. The Lafourche course from Donaldsonville to the Gulf was later abandoned in favor of the present course past New Orleans.

As a result of the alluviation and natural levee construction along the Teche and modern Lafourche meander belts of the Mississippi River, alluvial ridges occur on the eastern and western edges of the alluvial valley (Fig. 1). The central portion of the valley between the ridges remained a lowland—the Atchafalaya Basin. This lowland was completely enclosed at the south when the Lafourche delta overlapped the northeastern part of the Teche delta.

Northern section

The northern portion of the Atchafalaya Basin exhibits features typical of other parts of the alluvial valley which lies between Mississippi meander belts. While the basin is distinctly lower in elevation than the alluvial ridges which surround it, this northern portion is recognizably higher than areas farther south in the basin. Elevations of 40 ft. above mean Gulf level are common in the vicinity of Simmesport, and the surface slopes to about 10 ft. above sea level in the latitude of Krotz Springs. Under normal conditions the area above Krotz Springs is dry land. Studies of the topstratum of the northern part of the basin reveal that a pre-Teche course of the Mississippi River occupied part of it. Crevasse topography associated with Mississippi-size meander scars may still be seen, and borings have shown Mississippi River point-bar deposits at a number of locations. Further work is necessary to map this course accurately. After abandonment of the Teche course by the Mississippi, the history of the Atchafalaya Basin is dominated by the Red River, which, for the most part, followed the old Teche course of the Mississippi, but crevassed through the Teche ridge from time to time and established courses in the Atchafalaya Basin. Meander scars and drainage patterns characteristic of abandoned Red River courses, and information obtained from boring data, aid in establishing the position of these courses. Figure 3 shows former Red River courses in the

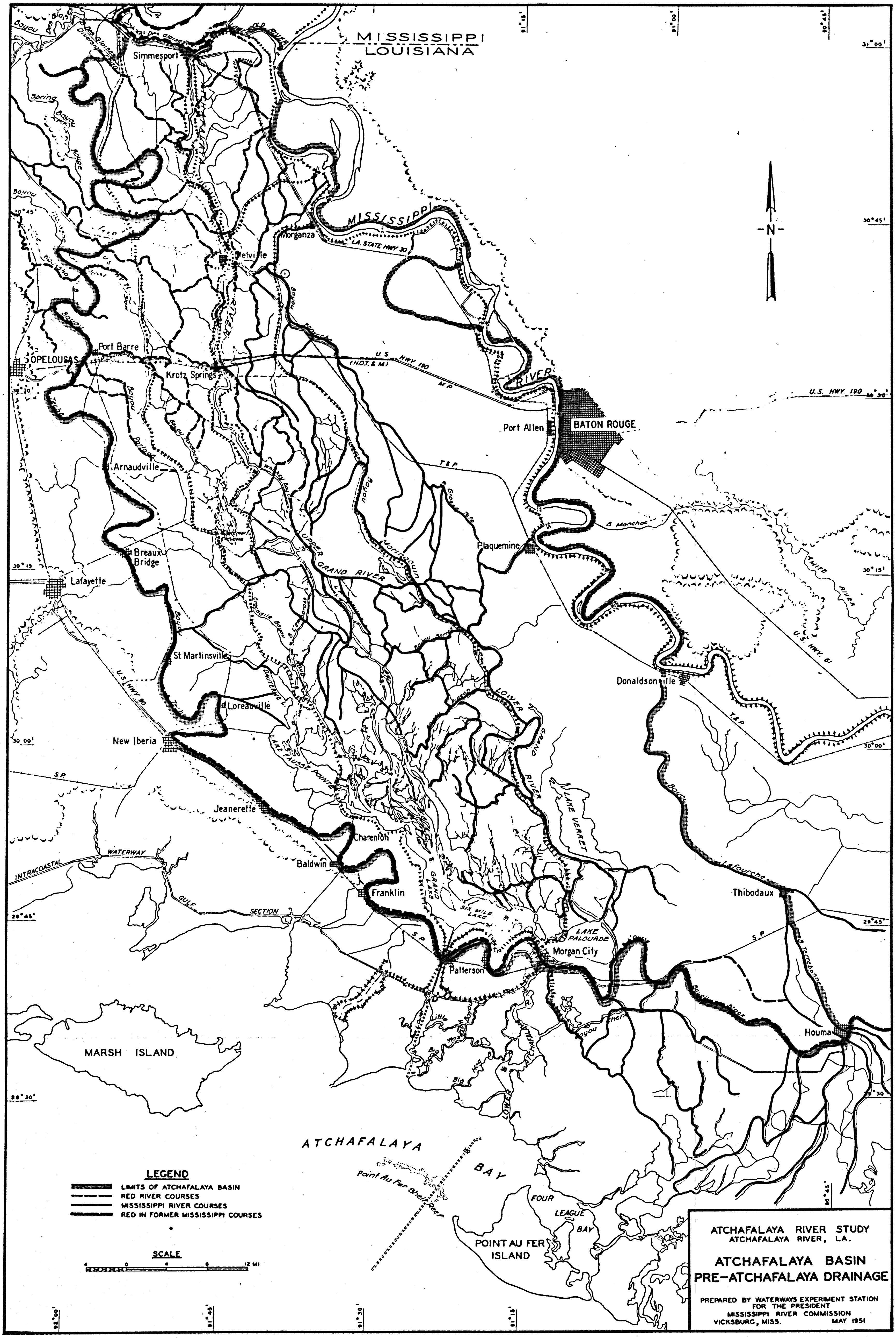
MISSISSIPPI
LOUISIANA
Simmesport
Morganza
Melville
Port Barre
OPELOUSAS
Krotz Springs
Port Allen
BATON ROUGE
Arnaudville
Plaquemine
Breaux Bridge
Lafayette
UPPER GRAND RIVER
St. Martinsville
Loreauville
LOWER GRAND RIVER
Donaldsonville
New Iberia
LAKE FAUSSE POINTE
Jeanerette
LAKE VERRET
Charenton
Baldwin
Franklin
INTRACOASTAL WATERWAY
GULF SECTION
GRAND LAKE
SIX MILE LAKE
LAKE PALOURDE
Morgan City
Patterson
Thibodaux
Houma
MARSH ISLAND
ATCHAFALAYA BAY
Point Au Fer Shell Reef
FOUR LEAGUE BAY
POINT AU FER ISLAND
MISSISSIPPI RIVER
U.S. HWY. 190
LA. STATE HWY 30
U.S. HWY. 61
U.S. HWY. 90
-N-
LEGEND
LIMITS OF ATCHAFALAYA BASIN
RED RIVER COURSES
MISSISSIPPI RIVER COURSES
RED IN FORMER MISSISSIPPI COURSES
SCALE
4 0 4 8 12 MI
ATCHAFALAYA RIVER STUDY
ATCHAFALAYA RIVER, LA.
ATCHAFALAYA BASIN
PRE-ATCHAFALAYA DRAINAGE
PREPARED BY WATERWAYS EXPERIMENT STATION
FOR THE PRESIDENT
MISSISSIPPI RIVER COMMISSION
VICKSBURG, MISS. MAY 1951

FIGURE 3

northern part of the basin. More work must be done before detailed tracing of all of these Red River courses in the basin proper can be accomplished, since subsequent alluviation has obscured them. It is certain, however, that the Red River occupied the Teche course after the Mississippi River abandoned it, and that later, the Red River wandered widely within the basin before it became established in a course now marked by Bayou des Glaises and Bayou Lettsworth. Aspects of Red River history in this part of the valley are discussed by Fisk.[6,7]

Southern section

The southern part of the basin, however, has a different history. The lower elevation of this sector is due in part to normal regional slope, but other factors are also important. It may be inferred from similarity of surface features that prior to the time the basin was limited on the south by the coalescing of the Teche and Lafourche deltas, much of the area south of Krotz Springs was occupied by a large coastal lake flanked by marshland such as may be seen in the Louisiana coastal lowlands. Modern remnants of the lake are present as Grand Lake, Six Mile Lake, and others. The prehistoric lake enlarged at the expense of marshlands as a result of subsidence and compaction of the latter. Northern limits of this lake were some distance north of the position indicated by the oldest available documents. Limits of the ancestral Grand Lake shown in Figure 1 were determined from data supplied by borings, distribution of Indian mounds and middens, and aerial photographs. The lake held brackish water, for shells of brackish water clams have been recovered from the borings and Indian middens.

The size of the lake has been gradually reduced by the enlargement of the Atchafalaya delta. Comparison of surveys made at periodic intervals shows that the area of Grand Lake has been reduced to a fraction of its former size, and that sediment is being deposited in the lake at an increasingly rapid rate from shallow deltaic distributaries of Upper Atchafalaya River. Continuation of the present trend will result in the complete filling of Grand Lake and Six Mile Lake.

The southern part of the Atchafalaya Basin is, therefore, largely a deltaic plain in which Atchafalaya River sediments continue to be built out over lake deposits and typical coastal marshlands. The present lake areas have lost their brackish character owing to fresh water flushing after the basin was isolated.

Origin of the Atchafalaya River

A variety of earlier published opinions regarding the origin of the Atchafalaya River have been reviewed in a preceding section of this appendix. Ideas concerning origin of the river, developed as a consequence of the present investigation, support some of the earlier views. Additional data must be secured and further study devoted to the problem before many details of the history may be documented.

There is little doubt that the Atchafalaya River originated before the coming of the white man to the area. However, no Indian mounds are found along the course of the river, indicating that the river is younger than most other large streams in this portion of the Mississippi Alluvial Valley. Studies made by Fisk[7] indicate that the conditions necessary for the formation of the river were established about 1500 A.D. These conditions involved the activity of the Red River prior to that time, and the growth of the Turnbull meander loop of the Mississippi River.

After a period during which the Red River occupied the abandoned Teche course of the Mississippi River and various courses in the northern part of the Atchafalaya Basin, it became established in a channel, a portion of which is now occupied by Bayou des Glaises to Simmesport, the Atchafalaya River from Simmesport to Lower Old River (former Marksville-Angola segment of past Teche-Mississippi course), and Bayou Lettsworth south of Lower Old River. Later the Red River shifted into its present course past Alexandria, Louisiana, re-entering the Atchafalaya Basin region, probably along a course of the Ouachita River, parallel to the Mississippi. The Red River was finally captured by the Mississippi by the growth of the Turnbull Island meander loop.

The Atchafalaya River was introduced into the Atchafalaya Basin after the capture of the Red River by the Mississippi River at the Turnbull Island meander loop. The river first broke through on the outside bend of the Turnbull loop and followed an arm of the Bayou des Glaises-Bayou Lettsworth-Red River course to the outside of another meander bend near Simmesport.

The reasons for the establishment of the Atchafalaya River course south of Simmesport are difficult to substantiate. There is the possibility that it followed an abandoned course of the Red River which was formed by diversion of the Red from its Bayou des Glaises course at Simmesport. There is also the possibility that the Red River, after it had been diverted to its present course north of Turnbull Island, and prior to its capture by the Mississippi River, followed a central course downvalley. In so doing it reoccupied that portion of its former Des Glaises course between what is now the head of the Atchafalaya River and Simmesport. In either of the above cases the Atchafalaya River would have reoccupied an old Red River course down the center of the basin.

There is a greater possibility that the Red River never flowed down the center of the basin in the position now occupied by the Atchafalaya below Simmesport. In this case, soon after the Red was captured by the Mississippi, the Atchafalaya likely began by crevassing on the outside of the Turnbull loop, occupied part of the old Bayou des Glaises-Lettsworth-Red River channel to Simmesport, whence it followed earlier crevasse channels of the Red and Mississippi Rivers down the center of the Atchafalaya Basin.

PART IV: MATERIALS COMPOSING THE BED AND BANKS OF THE ATCHAFALAYA RIVER

The materials composing the bed and banks of the Atchafalaya River have been grouped into two broad categories, following the classification developed in studies of the Mississippi River and its tributaries: (a) a predominantly sandy substratum, and (b) a relatively fine-grained topstratum. The first represents mainly materials deposited in response to the gradual rise of sea level which followed final retreat of the Pleistocene glaciers, but also includes a minor quantity of sediments deposited by ~~meandering rivers. The second constitutes a complex series of sedi-~~ ments deposited in, or adjacent to, river floodplains. The topstratum may be subdivided, according to environment of deposition, into natural levee, point-bar, abandoned channel, backswamp, and deltaic deposits.

The Substratum

The substratum consists predominantly of fairly clean sands and gravels laid down in a valley cut into older sediments during glacial times and filled during the present interglacial stage. The thickness of the unit ranges from about 160 ft. near the head of Old River (Plate A8) to over 400 ft. in the vicinity of Grand Lake (Plate A7) and probably continues to increase toward the Gulf. The configuration of that portion of the entrenched valley which lies below the Atchafalaya Basin has not been traced in detail. Indications are, however, that the deepest part of the trench is along a line running northwest-southeast through Lake Verret. The coarsest portions of the substratum are the gravels filling the deepest part of the entrenched valley. In Grand Lake these gravels begin at an average depth of 200 ft. Northward, near Old River, gravels occur at depths of less than 50 ft. The coarse sand and gravel at the base of the substratum ordinarily grade upward into medium and fine sand which marks the top of the unit.

Plates A4 and A5 show the 1950 thalweg superimposed on a generalized subsurface profile illustrating the composition of the bed and banks of the leveed section of the Atchafalaya River. There are many areas in this upper reach where the river is scouring into easily erodible substratum sands. The number of these areas has increased considerably as may be seen by a comparison of the 1950 thalweg with earlier ones, the 1904 thalweg for example. Graphs prepared by the Mississippi River Commission of the average channel bottom by reaches for a number of years show the magnitude of this over-all deepening of the channel. One of the most striking points noted when comparing earlier thalwegs with those of the present channel is the unevenness of the former, with individual "holes" scoured into the channel bed to depths not normally reached by the present channel. It is believed that this erratic profile, characteristic of the channel bottom during the earlier stages of Atchafalaya channel enlargement, was caused by the river's rapid scour in areas where it had broken through the topstratum into the less cohesive substratum materials. This resulted in undermining the more cohesive topstratum materials forming the adjacent bed and banks permitting the channel cross section to enlarge both vertically and laterally at an accelerated rate. This may explain the anomalous condition in the early Atchafalaya River noted by other writers[4,12] of a narrow channel often associated with a shallow depth, and greater depths associated with greater widths. Such conditions could only occur in newly formed channels which had not had time to adjust their cross sections to the volume of flow. It might be pointed out that with ever-increasing discharge, the Atchafalaya is continually adjusting its cross section to a new volume of flow. The fact that it is now scouring in loose substratum materials throughout most of its leveed section, however, enables it to adjust its channel more readily to its discharge, reduce the roughness, and increase channel efficiency.

The Topstratum

This term includes all materials overlying the substratum. The topstratum forms a wedge-like body, the average thickness of which increases from 40 ft. in the northern portion of the basin to more than 150 ft. in the southern part. The thickness and cohesive nature of this unit determine to a considerable extent the meandering characteristics and the rate of channel enlargement of the Atchafalaya River.

~~The boundary between this unit and the substratum is an irregular~~ one. Plate A3 shows contours drawn on this boundary in the northern portion of the Atchafalaya Basin and illustrate this irregularity. A normal sequence of topstratum deposition is typified by the backswamp deposits which ordinarily grade from the underlying fine sand of the substratum into sandy silts and heavy clays, and reflect the final stages of the rise in sea level and valley aggradation. Major irregularities in the relatively even lower surface of the topstratum are one of the criteria for recognizing abandoned courses of the Mississippi and Red Rivers. The deepest portions of the topstratum represent former thalweg positions of cutoff channels, which are sometimes filled with clays to a depth of 180 ft. The thinnest topstratum deposits are found in areas of point-bar deposition where as little as 25 ft. of topstratum thickness is not uncommon.

Distinction between topstratum and substratum is based chiefly on grain size of the deposits. The substratum is composed of sands and gravels; the topstratum ordinarily of finer-grained deposits. Since the environments of deposition of topstratum deposits are varied, the materials are heterogeneous and consist of the various types of alluvial deposits described in the following paragraphs.

Natural levee deposits

Natural levee deposits consist principally of silts and fine sands laid down by floodwaters when the river tops its banks and spreads out over the above-bank surface. They accumulate in the form of ridges flanking stream channels. Coarser materials are laid down nearest the banks while progressively finer materials predominate with increasing distance from the river. The width of natural levees is proportional to the volume of the stream which formed them; their height reflects the difference in water levels between ordinary floods and low water. The most extensive natural levee deposits in the Atchafalaya Basin are not those of the Atchafalaya River, but those of what are now minor streams which flow through or border it. For example, the natural levees flanking Bayous des Glaises, Teche, and Grosse Tete, which are all relict drainages marking former courses of the Mississippi or Red Rivers, are of greater areal extent than those which flank the Atchafalaya (Plates A1 and A2). Although the discharge through the Atchafalaya is considerably greater than that of the Red, the natural levee deposits along the Atchafalaya are insignificant in comparison. This is a reflection of two things: the recency of Atchafalaya River development as a major stream, and the construction of artificial levees before and during this development preventing normal formation of a natural levee system in the upper reaches of the river. Natural levees are forming at a conspicuous rate along the lower unleveed section of the river, and it is conceivable that their development along the lower courses will eventually become more pronounced than along the upper segment. Extensive fine sand and silty sand natural levee deposits have been formed along the river. Figure 4 shows the extent of one of the largest of these sand deposits at the abandoned Southern Pacific Railroad crossing near River Mile 60. The light material in the right foreground and extending along the right creek bank is natural levee fine sand and silt. The dark material beneath is backswamp clay. Figure 10 (page A30) shows a mechanical analysis curve typical of natural levee deposits which flank the lower reaches of the river.

Natural levee deposits possess some cohesion but are comparatively thin and, with the possible exception of point-bar deposits, are the least stable of the various materials composing the topstratum. The principal effect of the natural levees is that of confining water in a single channel, hastening scour, especially in the lower reaches of the river.

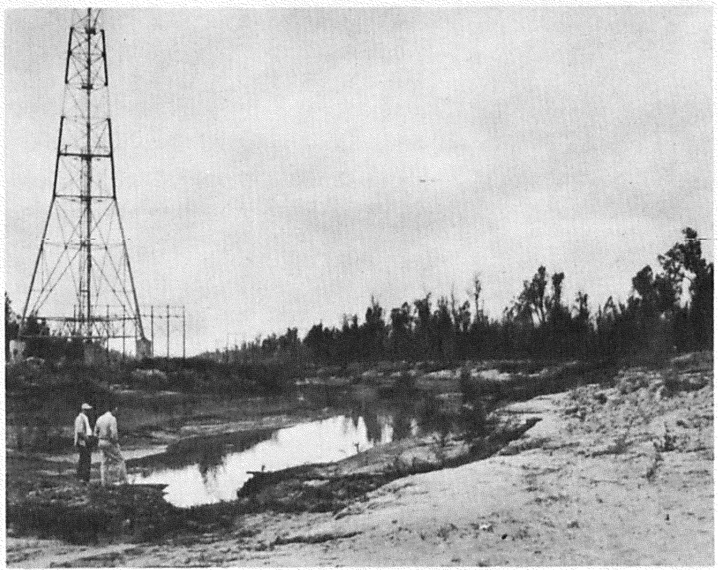

Figure 4. Fine sand deposits overlying backswamp clays at abandoned Southern Pacific Railroad crossing, River Mile 60, 1 December 1950

Point-bar deposits

Point bars consist of predominantly sandy deposits laid down on the inside of meander loops as the loops enlarge and migrate downstream. During this process a series of arcuate ridges is formed separated by intervening troughs, or swales, in which silts and clays are deposited. The aggregate is referred to as a point bar, or point-bar accretion, which may be further subdivided into swale fillings and sandy-ridge deposits. Topstratum is thinnest above point-bar accretion ridges, and is thickest over swales. The curvature and alignment of the ridges and swales reflect closely the size and shape of the meander loops in which they were laid down. Inasmuch as the radii of meander loops are proportional to the size of the stream, it is possible to distinguish point bars laid down by the Mississippi River from those formed by smaller streams such as the Atchafalaya and Red Rivers.

The surface distribution of point-bar materials is shown by Plates A1 and A2; those buried under cover of backswamp or natural levee deposits are cross-hatched. As these illustrations indicate, point-bar deposits occur only sporadically along the present channel of the Atchafalaya River, where they have been formed by rather slight migration of the channel. Broader and more conspicuous belts of point-bar materials cross the Atchafalaya River in the Simmesport sector, near Cypress Bend, and in the area south of Krotz Springs.

Point-bar deposits generally possess only slight cohesion. However, in instances where swale fillings are wide and extend to below the low-water level, these fine-grained, cohesive materials may by their relative resistance exert a minor control on the rate of channel migration or enlargement. Banks along the Atchafalaya composed of point-bar material retreat rapidly and evenly and relatively smooth bank lines are characteristic of such reaches. Figure 5 shows a reach of the Atchafalaya between River Miles 7 and 10 composed largely of point-bar materials.

Channel-fill deposits

The abandoned channel of a meander loop which has been separated from the

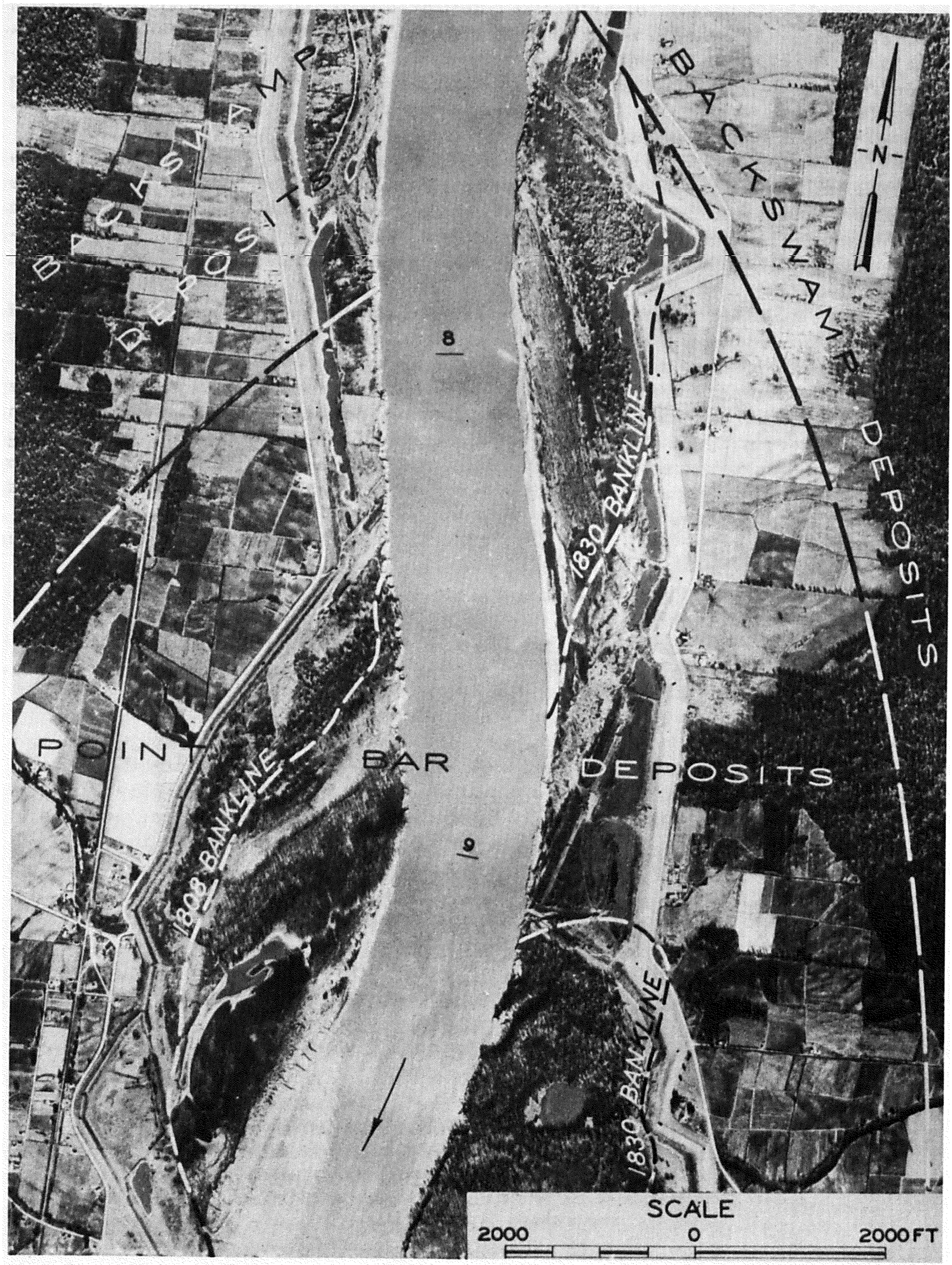

Figure 5. Reach along Atchafalaya River where bed and banks are composed principally of point-bar deposits. Note relatively smooth bank lines

main channel by a natural or artificial cutoff gradually fills with deposits of sands, silts, and clays. The slack-water area of the upper arm attracts coarser sediments from the main channel and rapidly seals itself off. The lower arm seals more slowly and normally with finer materials. The finest materials are laid down in the resulting oxbow lake which gradually fills with sediments carried to it by floodwaters. This thick clay deposit is commonly called a "clay plug."

Studies of the Lower Mississippi River have shown that the thick deposits of rather uniform clay laid down in abandoned channels often possess considerable resistance to erosion and act as "hard points" which tend greatly to retard the rate of bank recession and channel enlargement. This study indicates that the abandoned channel fillings in the vicinity of Simmesport and Cypress Point have acted in a similar way.

Bank recession is dependent not so much on the tenacity of cohesiveness of the topstratum materials into which the channel is cut, as on their thickness. It is the position of the substratum materials relative to the channel bottom which overwhelmingly influences bank recession in an individual reach. Once the channel has cut through the topstratum and into the underlying, comparatively loose substratum sands, rapid scouring of the sands causes unstable slopes to develop by removing support from beneath the topstratum. Bank caving results. Borings show that in the reaches at Simmesport and at Cypress Point, the river has not yet scoured its bed deeply enough to have penetrated the substratum.

Figure 6 illustrates to some extent the nature of the tight clay which fills the

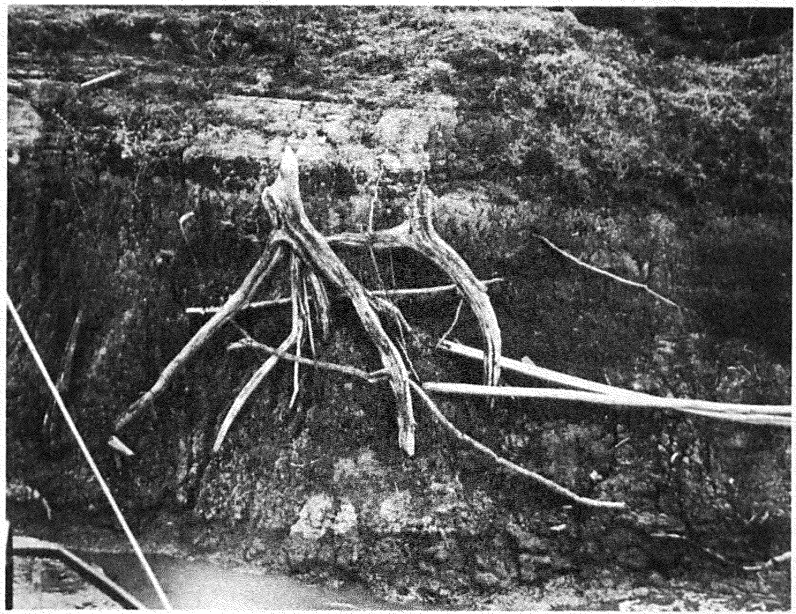

Figure 6. Tight clays in the lower arm of an abandoned channel fill at River Mile 19. Note cypress "knees" which indicate water level in the old oxbow lake prior to its becoming entirely filled with sediment. Top of riverbank at this point is an estimated 12 to 15 ft. above these cypress "knees"

lower arm of the abandoned channel at Cypress Point. Cypress knees pictured indicate water level in the old oxbow lake prior to its becoming entirely filled with sediment. Top of the bank of the river at this point is an estimated 12 to 15 ft. above these cypress knees. A large slump block occurring in the abandoned channel fill along the banks of Old River is illustrated in Figure 7. Here a relatively shallow channel-fill deposit has been undercut and has slumped into the river.

Figure 7. Slump block of relatively thin abandoned channel-fill materials at River Mile 4 on Old River. Note arcuate slump and angle which surface of block makes with the horizontal. Photograph taken 30 November 1950 during comparatively low stage of the river

Backswamp deposits

Backswamp deposits are the most extensive of the materials which form the bed and banks of the Atchafalaya River. They represent principally the long-continued accumulation of deposits in the low-lying areas which flank meander belts, and consist of clayey material which is not dropped at natural levee sites but remains in suspension until the waters are impounded in flood basins. The Atchafalaya Basin, situated between the Mississippi-Teche meander belt and the meander belts of the modern and Lafourche-Mississippi courses, is ideally located for the entrapment of floodwaters and the formation of backswamp deposits. Their thickness and lithologic character are remarkably uniform. Backswamp thicknesses in the northern end of the basin average 90 ft., gradually increasing to about 140 ft. in the Grand Lake area, where they are overlain by thin deposits of Atchafalaya deltaic deposits.

Backswamp deposits consist mainly of fat clays containing a high percentage of organic matter, and possess a resistance to river scour comparable to that of clay plugs. Their depth in the leveed reaches of the river is ordinarily not as great, however; consequently, they are subject to undercutting when the channel deepens sufficiently and the river cuts through them into the substratum. Sloughing of small segments into the river causes minor but relatively continuous bank caving where the comparatively loose silts and silty sands of point-bar deposits form the banks. On the other hand, large arcuate segments of the bank slump into the river where tough backswamp or channel-fill clays occur. These slump blocks act as natural revetments for some time until they, in turn, are removed by scour as deterrents to channel enlargement.

Figure 8 illustrates the serrated pattern of banks composed of cohesive

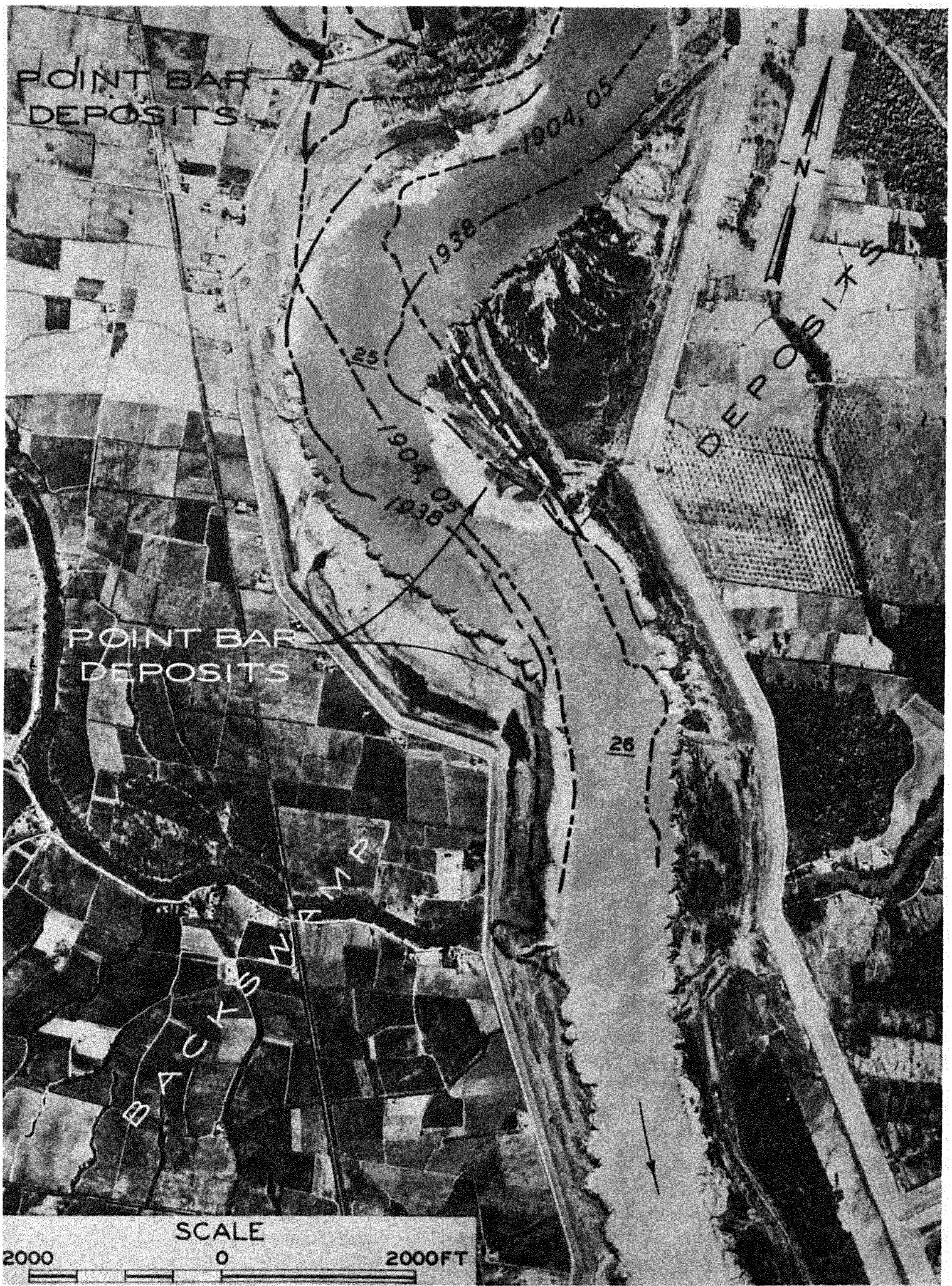

Figure 8. Reach along Atchafalaya River where bed and banks are composed principally of backswamp deposits. Note active slumping of banks on both sides of stream

clays. The reach pictured has banks composed almost entirely of backswamp deposits. Figure 8 shows a feature common along the Atchafalaya River: bank recession on both sides of a reach, an indication of active channel enlargement. Figure 9 shows a slump block of backswamp materials in the lower reaches of the river.

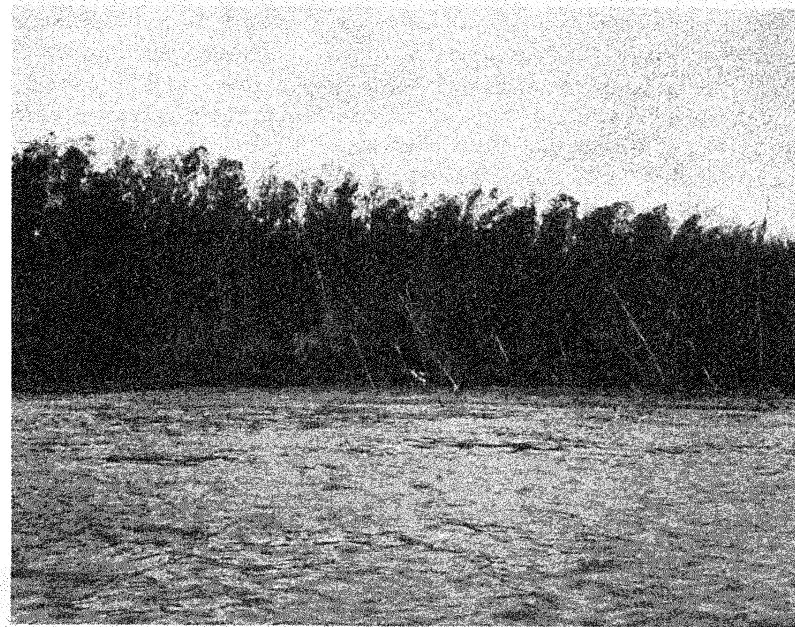

Figure 9. Slumping of backswamp materials at River Mile 66. The slump block has subsided beneath the water, but the trees that grew upon it and the angle that they make with the vertical indicate its extent and relative position. Photograph taken 1 December 1950

The block has subsided beneath the water, but the trees which grew upon it and the angle which they make with the vertical indicate the extent and relative position of the slump block.

Deltaic deposits

The Atchafalaya delta is a unique example of a large river discharging into and forming a delta in a body of still water. Alongshore currents and wave attack have not affected the delta's formation as they have in the case of the Mississippi River delta. Prior to the extensive dredging in the 1930's of the lower unleveed reaches of the river, water discharged through scores of small, inefficient channels which probably carried suspended sediment only short distances before loss of velocity caused deposition of most of the load carried. Recent dredging and work directed toward confining the flow to a single channel have resulted in an increased velocity and the discharge of a higher percentage of suspended sediment through the two outlets to the basin, the Lower Atchafalaya River and Wax Lake Outlet. Recent suspended sediment surveys have shown that regardless of the discharge and the resulting load of sediment carried by the Atchafalaya River, there is an excess of over 100,000 tons per day between the amount of sediment carried past Simmesport and the amount carried to the Gulf through the Lower Atchafalaya River and Wax Lake

Outlet. This is a rough estimation of the present rate of filling of Grand Lake with deltaic sediments. Bed load is not considered. Present studies do not indicate that it is an important factor in the growth of the Atchafalaya delta.

Accretion maps prepared by the New Orleans District show the phenomenal growth of the delta in recent years. Since 1930 more than 60 square miles of additional land surface has been formed in Grand Lake. Detailed shallow borings made in Grand Lake demonstrate the extent of this deposit in profile as well as in plan (Plates A28 to A30). The deltaic deposits are built outward over heavy, organic clays which represent the old lake bed and backswamp deposits formed before active Atchafalaya River delta-building began. The maximum thickness of the deltaic deposits is about 20 ft., the average approximately 15 ft.

The deltaic deposits can be divided on a color basis into two units (Plates A28, A29, and A30): a lower unit, distinctly red in color, overlain by a brown and gray-brown unit. In north-south section, the units tend to thin to the southward. The lower unit overlies thick gray and blue-gray lacustrine and backswamp clays. The contact between the thick clays and the deltaic deposits is marked by shell and wood accumulations. The red color of the lower unit reflects that stage of deltaic growth when only Red River sediments were carried by the Atchafalaya. The overlying brown and gray-brown unit illustrates the increasing discharge and consequent increase in sediment load diverted from the Mississippi River into the Atchafalaya. Exclusively Red River deposits form approximately 30 percent of the deltaic deposits in Grand Lake. Mixed Red River and Mississippi River deposits form the remaining 70 percent. Red River deposits consist of about 85 percent clay and 15 percent silty clay. Mixed Red and Mississippi River deposits consist of approximately 10 percent fine sand, 20 percent silty sand, 45 percent sandy silt, 15 percent silty clay, and 10 percent clay. The comparative fineness of the Red River deposits reflects deposition of this lower unit at a time when the head of the Atchafalaya delta was at a considerable distance upstream so that only finer sediments were carried to the present position of the delta. The coarse nature of the deltaic sediments in the upper unit is evident. Mechanical analyses of clay samples in the lower unit were compared with the thick lacustrine and backswamp clays which lie below and the latter were found to be far more consistent and much finer grained. Figure 10 contrasts the grain-size distribution of three samples selected from the deltaic deposits with that of the gray backswamp clay which they overlie, and with suspended load and natural levee samples. Figure 10a contrasts the grain-size distribution of bed-load samples from the Mississippi, Old, and Atchafalaya Rivers.

No attempt has been made in the present study to examine in detail the data which have been collected on bed-load and suspended-load sediments and to correlate these data with the deltaic deposits in Grand Lake. However, a few preliminary observations are warranted concerning the grain-size distribution curves shown on Figures 10 and 10a. Grain-size distribution curves 3 and 4 (Fig. 10) represent about 65 percent of the soil types which form the present deltaic deposits. About 25 percent of the remaining deposits are composed of silt and clay, and approximately 10 percent of fine-grained sand. Atchafalaya River bed load (curve 4, Fig. 10a) is composed of particles 60 percent of which are coarser than fine sand. Consequently, bed-load movement is considered as a relatively unimportant process in the building of the Atchafalaya delta. The increase in coarser material in the upper strata of the deltaic deposits (Plates A29 and A30) indicates an increasing importance of bed-load movement in the future. Grain-size analysis of the suspended load (curve 6, Fig. 10) shows a high percentage of fines which are not deposited in Grand Lake, but are apparently carried through the Lower Atchafalaya River and Wax Lake Outlet to the sea.

Figure 10a shows the striking fineness of Atchafalaya River bed load when compared with that of the Mississippi. Bed-load data published in 1935[20] were averaged for 14 samples taken on the Mississippi approximately 10 miles above and

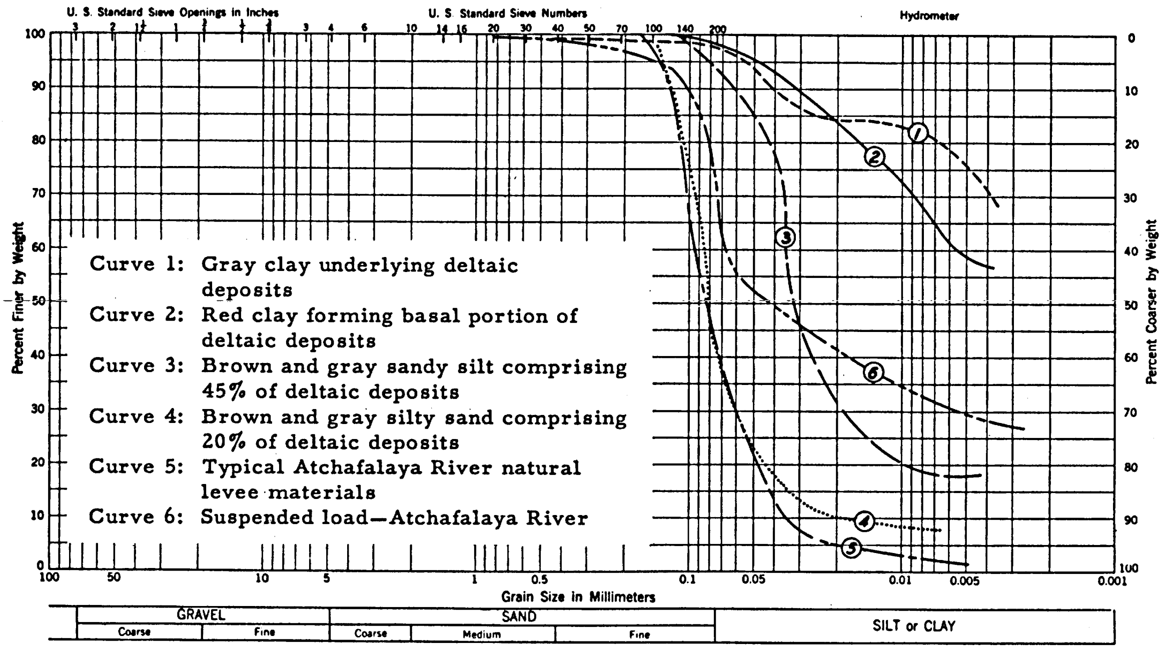

Figure 10. Comparative grain-size distribution curves

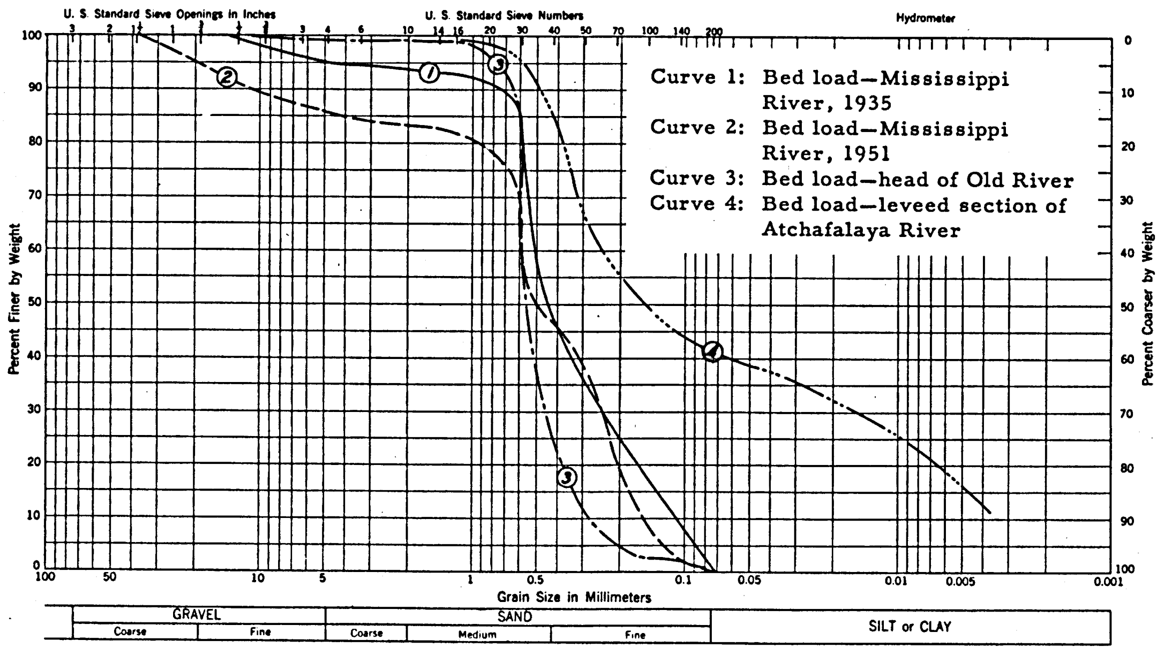

Figure 10a. Comparative grain-size distribution curves

below Old River and are shown as curve 1. Curve 2 is based on the average of six samples taken above and below the mouth of Old River in 1951. Curve 4 shows an average of eleven bed-load samples taken in the leveed portion of the Atchafalaya River. The relative coarseness of the Mississippi River bed load may indicate that little, if any, Mississippi River bed load is diverted into Old River and thence down the Atchafalaya.

An interesting fact which has been brought out by the recent surveys is the coarse-grained bed load which occurs in that reach of Old River between the Mississippi and the abandoned railroad bridge near Torras, Louisiana (curve 3, Fig. 10a). Samples taken 3/4 mile upstream from the bridge and 1/2 mile below the bridge show an extremely coarse bed load.* The most recent hydrographic surveys show a hole scoured to a depth as great as the thalweg of the Mississippi River at Carr Point and extending downstream in the Old River channel to the vicinity of the abandoned bridge. The channel bottom rises here to an average elevation of 30 ft. or more above that of the Mississippi. This rise in channel bottom at the point of diversion is envisioned as having the effect of a "skimming weir" which selects the fines in Mississippi River bed load and carries them down the Atchafalaya but leaves the coarse material behind. This effect should be less as the difference in channel bottom elevation at the diversion point is reduced. Considerable portions of coarse bed load from the Mississippi River may then be carried down the Atchafalaya to increase the rate of delta-building in Grand Lake.

Effect of Bed and Banks on Channel Enlargement

It was originally intended that this section of the appendix describe the bed and bank materials of the leveed portion of the Atchafalaya River by the five-mile reaches which have been used in preparing much of the engineering data (Appendix B) on the project. An attempt was made to utilize these reaches in the bed and bank investigation, but no correlations could be made. Two or sometimes as many as three distinct depositional types lie within a single reach or overlap two reaches, thus making comparisons between reaches meaningless. Reaches have, therefore, been regrouped based on types of deposits forming the bed and banks.

Old River reach

This reach strikingly demonstrates the control exercised by an abandoned channel on subsequent drainage alignment. Old River follows the thalweg position of the Mississippi River prior to Shreve's Cutoff in 1831.

Details of Shreve's Cutoff and the rapid deterioration of the cutoff channel are described elsewhere.[4] Briefly, the Red River, which entered the Mississippi at the upper arm of Turnbull Island Bend, continued to occupy this arm immediately following the cutoff. Soon only a small drainage channel remained in the lower arm marking the position of the former Mississippi River thalweg. A complicated history of this channel's development followed. It includes maintenance by flood flows on the Red and the Mississippi, dredging, shifting of the path of Red River's flow from the upper arm of the cutoff to the lower arm and finally the gradually increasing discharge of Mississippi River water through the lower arm into the Atchafalaya. Throughout this latter history the river has enlarged its channel and has closely followed the position of the former Mississippi thalweg. In so doing, the present channel is flanked by abandoned channel deposits on its south bank for the first two miles

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* A sand and gravel hydraulic fill placed in the abandoned Old River channel following Carr Point Cutoff (1944) may account for the coarseness of bed load in this reach.

of the reach, on both banks at the location of the old Mississippi River crossing, and on its north bank for the remaining two miles before its junction with the Atchafalaya.

As illustrated in various sections which cross the river in this reach (Sections A-A', C-C', D-D', E-E' and F-F', Plates A8, A9, and A10) there is a tendency for the river to increase its cross-sectional area at the expense of the shallow point-bar deposits which border the abandoned channel position first on its northern and then on its southern side. The most stable section of this reach is considered to be that portion at the former crossing, or at River Mile 4.5 to 5.5 where the present channel is flanked on both sides by channel-fill deposits. The bend caused by the change in stream alignment at the crossing, however, has begun to migrate downstream (toward the head of the Atchafalaya) and recent bar-building is in evidence. The point-bar deposits built here as the bend continues to migrate tend to nullify the controlling effect that tighter channel-fill deposits, which originally formed the banks, might have on over-all channel enlargement. In addition, it should be noted (see Plate A8) that the deposits that fill this abandoned channel are not the usual deep, tight clays that fill abandoned cutoffs. The normal sequence of filling was complicated by the fact that the Red River discharged into it and deposition of coarser sands, silts, and silty sands resulted. Section B-B' (Plate A8) illustrates the coarse nature of this fill near the junction of Old River and the Mississippi and its gradual increase in clay content west from the point of cutoff.

Reach 0.0-5.0

Sections illustrative of this reach are G-G', I-I', J-J', and M-M', Plates A10, A11 and A12. The materials composing the bed and banks are almost exclusively point-bar deposits. Sand substratum lies at depths as shallow as 25 ft. and is sometimes exposed along the banks during low-water stages of the river.

The reach lies in an area which was formerly a part of the meander belt of the Mississippi River. The southern limit of the meander area is marked by Bayou des Glaises on the west of the Atchafalaya River and extends across the river at Simmesport in a broad arc shown on Plate A1. An abandoned cutoff channel occurs in this reach near River Mile 3. The clay plugs formed in the upstream and downstream arm of this abandoned channel probably influenced the course of the ancient Mississippi River following cutoff of the bend and may account for the two meanders in the reach. There is good reason to believe that subsequent to abandonment of this course by the Mississippi River the Red River followed Bayou des Glaises, swung northward along the present Atchafalaya channel at Simmesport, and continuing down Bayou Lettsworth, emptied into the Raccourci Bend of the Mississippi River near the present town of Williamsport. Long occupation of this reach by both the Mississippi River and the Red River have effectively isolated the clay plugs by building up point-bar deposits between them and the present channel, so much so that they exert little control on the present course or rate of channel enlargement of the Atchafalaya.

Reach 5.0-6.5

Immediately south of the entrance of Bayou des Glaises into the Atchafalaya River is a thick clay body which may be a portion of a clay plug (Sections K-K' and L-L', Plate A12). Clay in this area extends to a depth 60 or more feet below the deepest portion of the channel. Possible scars on the alluvial surface which might have been used for determining a more accurate location of the clay body are effectively buried under the thick natural levees which are present in the Simmesport area. The position of the clay plug is fairly accurately known where it forms the bed and banks of the Atchafalaya. The probable location of the entire plug is shown on Plate A1. Southward from the clay body is a continuation of fairly deep, tenacious clays of backswamp origin (Sections N-N' and D-D', Plate A13).

This reach is considered one of primary importance since it confines the Atchafalaya River within essentially tight materials and is the uppermost of what might be called the "control" reaches.

Reach 6.5-14.5

The most conspicuous meandering along the Atchafalaya River occurs in this reach. Maps comparing historic bank lines show that the extent of change in channel alignment has been considerable. Section Q-Q' (Plate A15) shows a lateral migration of the channel at this point of nearly 4000 ft. since 1904, and of more than two miles, judging by the extent of deposition of Atchafalaya River point-bar deposits, since it began to meander. This lateral migration into what must have been tough backswamp clays, similar to those in the previous reach, seems to have been the result of the controlling influence of the clay plug just downstream from this reach described in subsequent paragraphs. Sections P-P' (Plate A14), Q-Q' and R-R' (Plate A15) show the existence of a clay stratum below the normal depth of scour of the Atchafalaya. This is backswamp material and, though locally overlain by Atchafalaya point-bar deposits, probably exerts some influence on channel enlargement, especially on the rate at which the channel deepens.

Cypress Point reach, River Miles 14.5-20.5

It is necessary to divide this reach into three segments, River Miles 14.5-15.5, 15.5-18.5, and 18.5-20.5, in order to evaluate adequately the effect of the stability of the bed and banks on channel enlargement in the reach. For purposes of description, however, the three are described as a single unit, a unit controlled entirely by two arms of a clay plug which lie across the course of the Atchafalaya. The upper arm of this clay plug is the direct cause of what appears to be an abnormally large river meander at Cypress Point. The present study has shown that Cypress Point is not the result of accretions enlarging a river bend, but rather is due to the clay plug. Bank-line surveys dating as far back as 1810 show that the bend has remained essentially stable and that the Atchafalaya River has had little success in wearing away the clays which compose it. Plate A16 shows the position of this clay plug as determined by borings and scars left on the alluvial surface. Plates A16 through A19 show details of the bed and bank deposits within the reach. The stability of the Cypress Point segment from River Mile 14.5-15.5 is in direct contrast to the intermediate segment from River Mile 15.5-18.5, where the Atchafalaya has meandered at will in the shallow point-bar materials which lie between the two arms of the clay plug. A more confined system of meanders has occurred in the materials forming the lower arm, possibly initiated by the meanders in the intermediate segment.

The controlling effect of the Cypress Point reach cannot be overemphasized. The confining effect of the plug in the upstream arm, by resisting passage of river waters, probably flattened the gradient above that point and was the cause of the extensive meandering in the reach immediately upstream. No flattening of the gradient is evident in this upstream reach at the present time and the river has straightened materially resulting in a shortening of 0.8 mile in this reach (Miles 6.5-14.5) since 1917 and 2.2 miles since 1881. A similar tendency for the river to cease meandering and shorten its path is noted between Miles 15.5 and 18.5

Reach 20.5-46.5

The bed and banks of this extensive reach are characterized throughout by heavy backswamp clays which consistently reach depths of -60 to -70 ft. m.s.l., or a thickness of from 90 to 100 ft. The type of material forming the bed and banks in this reach is so very much alike that it is considered as a unit although minor irregularities occur in the over-all pattern.

Sections Y-Y' through KK-KK' (Plates A19 to A26) show subsurface conditions in this reach. All but two of these sections are immediately adjacent to the river and show a rather consistent depth of the backswamp clays, with a slight thickening southward. Two of the sections, HH-HH' (Plate A23) and JJ-JJ' (Plate A25) extend for several miles to the east and west of the river and further illustrate the homogeneity of the backswamp clays in transverse as well as longitudinal profile. The pattern is interrupted slightly by point-bar deposits from old Mississippi meander courses and distributaries, but the continuity of the clays, especially adjacent to the river, is well illustrated.

Generally speaking, this reach is remarkably stable. Bank-line surveys show almost no change in channel alignment since the early 1800's. Less than one mile of shortening has occurred in this 26-mile reach since 1917, and only about 1.5 miles since 1881. A small meander at Mile 26 is migrating downstream at a very uniform rate, attesting to the homogeneity of the bed and banks in the area. On the other hand, a small bend immediately downstream from Melville, River Mile 32, has shown little tendency to migrate. An oddly shaped bend, much larger than the previous two, exists near the southern limits of the reach at Mile 44.5. This bend has also remained stationary. Borings within the bend and across the river from it (Section KK-KK', Plate A26) show thick clays which may represent a continuation of the backswamp clays typical of this reach or a clay plug which may have diverted the river's course as in the case of the clay plug at Cypress Point. Subsurface information is too scattered in this area, however, to permit positive identification. Although the bed and banks of most of this reach are of backswamp materials, several small segments are composed of point-bar deposits. These are in areas where slight meandering has occurred and are delineated on Plates A1 and A2.

Comparative thalwegs for 1904, 1938, and 1950 are superimposed on three of the longitudinal sections in this reach (Sections BB-BB', DD-DD' and EE-EE', Plates A20, A21 and A22). The comparative irregularity of the thalwegs in the earlier years and the tendency to fill in the deeps and level off the highs to form a smoother thalweg is noted in the later years. The over-all deepening of the thalweg is also illustrated. The 1950 thalweg of the present river is now at such a depth that it is scouring into the sandy substratum in a number of places. This reach is considered the most stable of those in the leveed section of the river and is regarded as the principal control from the viewpoint of material type control to channel enlargement of the Atchafalaya River.

Reach 46.5-56.5

This reach is characterized by a fairly shallow topstratum. Details are shown on Sections LL-LL' (Plate A26) and MM-MM' and NN-NN' (Plate A27). Section NN-NN' shows the dividing line between this reach and the typical backswamp reach above. The topstratum in this reach is composed consistently of point-bar deposits laid down along what was, at least in part, a distributary system of the Mississippi when it was in its Teche course. There seems ample evidence to substantiate the existence of a meander belt in this area of either Mississippi or Red River origin which the Atchafalaya crossed in its down-valley course. The upper limit of the resulting point-bar deposits has been determined as Mile 46.5. The lower limits are uncertain but can be placed around Mile 70, approximately 12 miles below the end of the leveed section of the river. Little or no control of channel enlargement is exerted by the bed and bank materials in this reach.

Unleveed reach

No detailed information has been gathered on the type of deposits which form the bed and banks of the Atchafalaya River beyond the end of the levees. As mentioned above, point-bar topstratum deposits extend as far south as River Mile 70; beyond this, generalized subsurface profiles (Plates A6 and A7) show a rather consistent heavy clay stratum which lies below relatively thin deltaic deposits of the Atchafalaya River. The deltaic deposits are in most instances composed of silts, silty clays, and silty sands, and, as such, offer little resistance to channel enlargement. Their depth normally increases southward. The fairly continuous heavy clay stratum that lies below these deltaic deposits forms the major portion of the bed and banks of the shallow channel in which the river flows.

Natural channel enlargement is not an important factor in this reach. Rather than scour its bed and banks, the river takes a path of less resistance and tops its banks. As natural levees are built up along this lower reach, however, and as volume of discharge continues to increase, heavier scour will be concentrated in the river channel and the deposits that form the bed and banks of this reach may become of greater importance.

Channel enlargement vs. material type

No firm conclusions can be offered as to the effect of the stability of the bed and banks until all, or as many, data as possible have been collected, each series of observations put in its proper perspective, and analyzed as to its effect on increasing discharge. A recalculation of all cross-sectional elements available in each of the reaches selected above on the basis of the type of deposits which forms the bed and banks, and averaged by these reaches, should give a more conclusive estimate of the effect of bed and bank materials on cross-sectional enlargement. Table 1 presents a comparison of channel cross sections along a range in each of these reaches. Annual discharge data are listed because of their apparent intimate connection with cross-sectional enlargement and deterioration. Other data, such as extension of artificial levees, dredging of the lower reaches of the river, and the date of Carr Point Cutoff, are given because it is felt that their effect on channel enlargement has been considerable.

It has been found that the three most stable reaches in the leveed section of the river are those between River Miles 5.0-6.5, 14.5-15.5, and 20.5-46.5. There is no evidence of meandering in the first two reaches, and only very slight meandering in the last 26-mile reach. In each instance, the bed and banks of the reaches are composed of channel-fill or backswamp clays which extend to depths greater than present river scour. It is safe to assume that whatever control is exerted on overall channel enlargement by the bed and banks of the Atchafalaya, is, or may once have been, caused by these reaches. Figure 11, a graphic comparison of the cross-sectional data listed in Table 1, shows that before the early 1930's ranges 69 and 174 showed little tendency to enlarge. The rather rapid enlargement of both of these cross sections since that time may indicate that they have ceased to function as important controls to channel enlargement. Comparing all the ranges listed in Table 1, it is seen that cross-sectional enlargement can be closely correlated with annual discharge, especially in the four Atchafalaya River ranges above Cypress Point. Each increase in discharge is faithfully duplicated by channel enlargement and each drop in discharge by channel deterioration. Ranges 174, 354, and 434 are not nearly so sensitive to variation in discharge. This appears to indicate that the other reaches, composed mostly of loose point-bar and substratum sands, adjust themselves readily to fluctuations in discharge. The more stable reaches did not enlarge as readily when discharge increased, but raised stages within the reach to accommodate flow. When

Table 1

CHANGES IN CROSS-SECTIONAL AREAS OF SELECTED RANGES WITH TIME

Year	Old River: Annual Discharge at Simmesport in Thousand Day-sec.-ft.	Old River: Old River Reach River Mile 3.0 Range No. 45	Atchafalaya River: Reach 0.0-5.0 River Mile 1.2 Range No. 16	Atchafalaya River: Reach 5.0-6.5 River Mile 5.7 Range No. 69	Atchafalaya River: Reach 6.5-14.5 River Mile 7.6 Range No. 93	Cypress Point Reach: Reach 14.5-15.5 River Mile 15.2 Range No. 174	Cypress Point Reach: Reach 15.5-18.5 River Mile 18.0 Range No. 203	Cypress Point Reach: Reach 18.5-20.5 River Mile 19.5 Range No. 220	Reach 20.5-46.54: River Mile 31.3 Range No. 354	Reach 20.5-46.54: River Mile 38.3 Range No. 434	Reach 46.5-56.5 River Mile 51.6 Range No. 583	Extension of Levee System in Miles Below Head of Atchafalaya River: East Bank	Extension of Levee System in Miles Below Head of Atchafalaya River: West Bank
		Bankfull Cross-Sectional Areas in Square Feet											
1881			42,090	49,485	46,944	56,297	39,562	40,996	28,438	19,739		13	26
1904		22,345	48,987	51,994	54,010	55,084	47,037	54,380	45,178	34,140	13,480	43	38
1916	51,386		54,056	60,795	62,490	60,090	52,235	54,453	47,690	43,670	22,520	48	52
1927	87,128		68,108		77,156	52,588	64,389	76,403	52,297	47,193	36,424	55	52
1931	21,097		49,435	54,430	62,700	62,010	65,530	78,690	55,730	53,160	40,145		
1932*	50,874		59,160	67,715	71,130	65,415	69,600	82,180	55,930	55,545	39,175		
1933	52,925		59,788	70,326	73,131	64,652	70,451	88,242	57,081	56,659	43,686		
1934	26,207		52,717	62,076	64,139	62,180	63,931	78,475	57,013	56,034	40,390		
1935	64,605		61,670	65,610	74,035	63,445	71,060	73,315	56,125	57,465	45,150	55	57
1936	31,276			69,260	73,840							55	67
1937	57,830	48,160	57,791	68,280			74,240	74,916		59,400	53,539		
1938	58,608	46,840	59,400	67,400	72,280	67,600	71,600	67,680	64,760	58,960	76,360		
1944†	57,375	46,800	66,280	70,960	74,080	81,200	66,572	65,720	64,120	55,920	96,200		
1945		48,680	64,803	74,280	79,880	87,440	99,684	72,615	75,040	62,000	116,618		
1950	108,894	51,060	81,987	80,755	81,865	104,320	93,840	84,460	82,960	71,520	105,600		
		Deposits Forming Reach‡											
		CF&PB	PB	CF&BS	PB	CF	PB	CF	BS	BS	PB		

* Extensive dredging of Lower Basin begun in 1932. Approx. 90,000,000 cu. yd. of earth dredged 1932-40.
† Carr Point Cutoff, December 1944.
‡ CF indicates channel fill, PB point bar, BS backswamp.
Note: River mileage based on quadrangles.

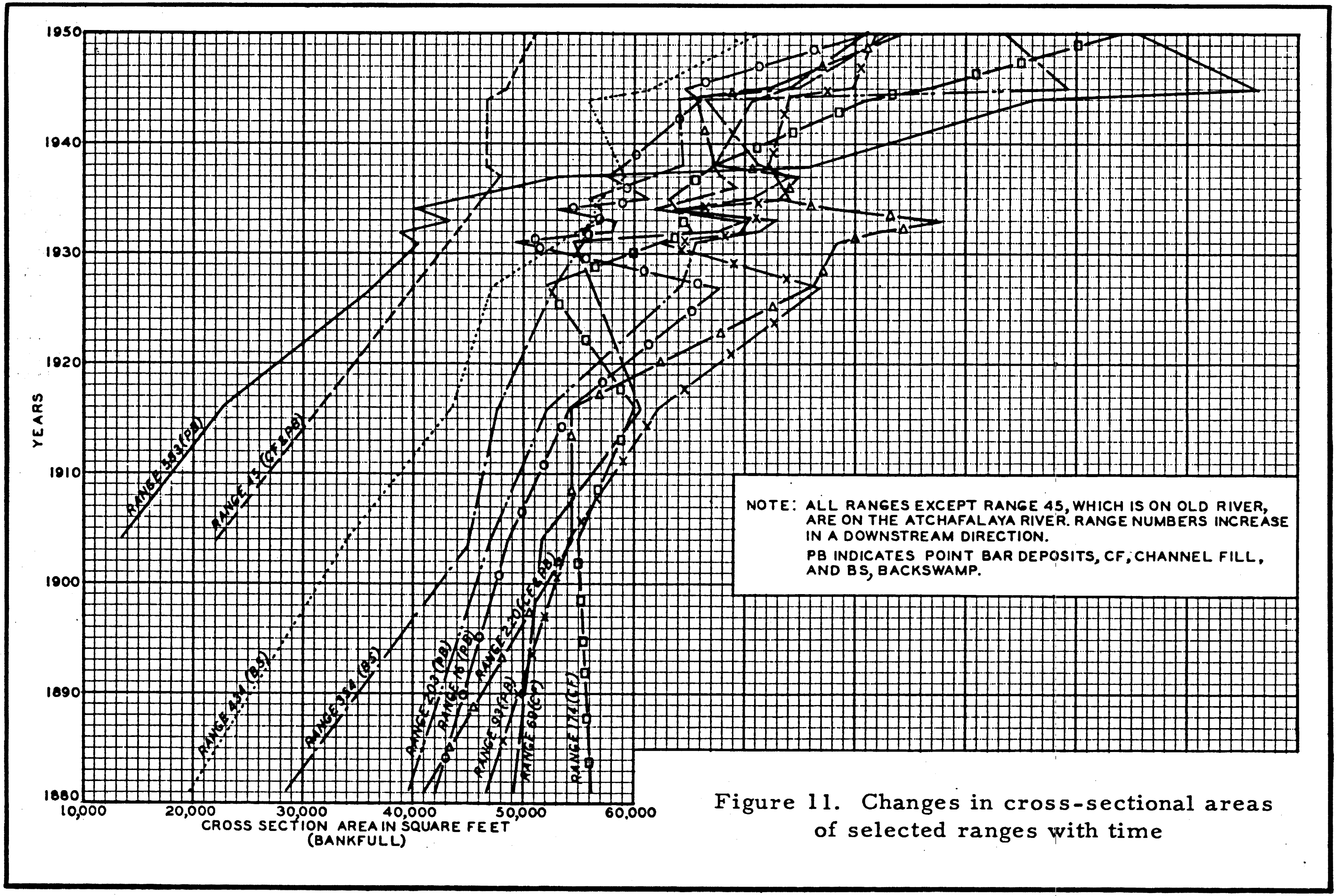

Figure 11. Changes in cross-sectional areas of selected ranges with time

discharge decreased, stages subsided and cross-sectional areas did not deteriorate to the marked degree noted in the less stable reaches. The implication is that the stability of these reaches is one of the controlling factors in channel enlargement.

The most important consideration, however, is that as the channel continues to deepen and penetrates more and more into substratum sands, whatever control the stable reaches now exert on channel enlargement will be lessened. In short, the controlling effect of cohesive materials in the bed and banks of these reaches is diminishing as discharge increases.

The increase in cross section of nearly all the ranges, which took place during years of high discharge, is notable. The trend is toward gradual channel enlargement; however, years of low discharge and consequent channel deterioration are followed by years of high discharge during which the products of deterioration are removed and over-all channel enlargement occurs. The effect of two successive flood years, or two or three consecutive years of high discharge, on the rate of channel enlargement might be critical in rapid diversion of the Mississippi into the Atchafalaya.

PART V: MISSISSIPPI RIVER DIVERSION AND DISTRIBUTARY DEVELOPMENT

Mississippi River Diversions

The building and subsequent abandonment of meander belts has occurred repeatedly in the development of the alluvial valley of the Mississippi River. Gradual shifting of the Mississippi River from one side of its valley to the other has not occurred. The channel is restricted to a meander belt within which it shifts, but from which it rarely escapes. Meander loops grow within this belt and are abandoned through chute or neck cutoffs, with the result that the channel again finds itself centrally located in the meander belt. Natural levees, which represent the coarsest suspended load of the stream, flank the main channel and rise notably above the elevation of the adjacent backswamps. In time the seaward lengthening of the channel causes the gradient to become so low that the river seeks a new and shorter path to the sea.

The best defined ancient courses in the southern part of the Lower Mississippi Valley are the Walnut Bayou (Teche-Mississippi), which lies close to the western valley wall in southern Louisiana, and the Lafourche-Mississippi, which extends southward from the modern river course at Donaldsonville, Louisiana. Between these meander belts is the lowland of the Atchafalaya Basin, an ideal path for the next major diversion of the Mississippi River.

The cause of the diversion which ultimately brought about the abandonment of each of the full-flow courses of the river must be largely conjectural because subsequent migration has destroyed the direct evidence of local relationships which existed when the initial diversion occurred. The regional relationships clearly show, however, that each new course developed because it held a gradient advantage providing a shorter route to the sea. These is some evidence to demonstrate that each development probably was initiated when an enlarging bend of the stream intersected a channel on the alluvial plain which was of sufficient depth to carry low stage flow from the river. There is enough evidence in each area where a diversion has occurred to demonstrate that the developing stream left the river at a low or an acute downstream angle with the main channel.

The progressive deterioration of the channel as increasingly large amounts of water are diverted is readily seen along each of the abandoned courses. The former main channel is narrowed and locally straightened during the period of diminishing flow. Accretion ridges and swales of a size comparable to those along the present Mississippi River give way to narrow accretion ridges, minor natural levees, and elongated narrow lakes which fill an area as wide as the former river channel. No evidence of channel migration (meandering) is visible in the channel filling, and it is therefore safe to assume that stream discharge must have been greatly decreased before channel deterioration set in. Evidences of rapid deterioration of the channel in process of being abandoned are interpreted as indicating rapid capture of the old stream after the main volume of discharge began to be directed down the new course.

Geological information indicates that the initial stages of each diversion took place very slowly. At a certain critical stage, water flowing through the main channel was insufficient to maintain it and rapid deterioration set in. Deterioration of the main channel added a further impetus to diversion until little low-water discharge could pass through the old channel. It then ceased to function.

Distributary Development

It is reasonable to assume that factors which control the growth of distributaries of the Mississippi River below Head of Passes are similar to those which control the downstream development of the Atchafalaya River. Formation of deltaic distributaries is a relatively rapid process, a process which is amply documented by historical records.

The Mississippi distributaries lengthen their courses and widen and deepen their channels in maintaining river flow across the modern delta. Silts and sands carried by the river are deposited and the clays flocculate when they come in contact with salt water in the vicinity of the mouths of distributaries and, in settling, gradually build up the floor of the Gulf. Sands translated downstream as bed load are segregated in river mouth bars. These bars restrict the channel and divide it into several offshore threads, each of which eventually develops into a new distributary.

~~During high stages, when the river overflows its banks, sands, silts~~ and clays are dropped close to the channel to form low natural levee ridges. These levees are first constructed under water just beyond the mouth of a distributary. With successive floods, the levees are built to sea level and the surrounding Gulf bottom is aggraded. Sedges and grasses begin to grow when the levees reach the water surface and help to trap more sediment. The levees are eventually built up to several feet above sea level and aid in confining the flow and increasing the discharge through the channel during high stages. As a result the channel is more rapidly deepened and widened after the levees have been built above the sea.

During the build-out of the delta a distributary with a favored alignment receives a greater volume of flow and is extended seaward beyond the others, eventually becoming the main channel of the river. Less favored distributaries are abandoned; their channels are filled with sand and they are finally sealed off from the river by growth of natural levees. The positions of these abandoned distributaries are marked by minor water bodies and by low natural levee ridges which rise slightly above the marsh surface, like veins in a leaf. In areas where wave attack and subsidence destroy the marshlands, the natural levees which border the channel are the last to disappear. A similar sequence of events is taking place in the growth of the Atchafalaya delta.

Distributary courses tend to straighten as they receive a greater part of the river's discharge. Such tendencies can be seen in many streams, both in the modern Mississippi distributaries below Head of Passes, and in the abandoned distributaries of the Teche-Mississippi and the Lafourche-Mississippi deltas. Most of the active passes of the Mississippi are flanked by anastomosing networks of minor distributaries or by crooked tidal channels. The relationship which these streams bear to the main distributary is such that each must have originated as a minor pass of the Mississippi. There can be little doubt that each active distributary maintained its initial flow in a relatively tortuous channel and that only those with favored alignment received sufficient flow to be maintained as distributaries.

Straightening of distributaries is accompanied by some widening of the channel and by great deepening, a development characteristic of streams cutting into thick cohesive clays. Abandoned distributaries in the ancient deltas of the Lafourche-Mississippi and Teche-Mississippi have been tested to determine the depths to which their channels were scoured. The sand filling of these channels is known to extend to over 175 ft. or to depths comparable to scouring in the Mississippi River below New Orleans. Maximum depths of scour in the leveed reaches of the Atchafalaya River is in the neighborhood of 160 ft. Scouring in the lower reaches of the river is practically nonexistent; the channel must be maintained by dredging.

All evidence points to straightening, widening, and deepening of the distributaries as the delta is prograded seaward. These effects are the direct result of increased discharge through a given channel and appear to be the normal effect of stream action on the low slopes of the near-sea-level deltaic plain. They should be taken into consideration when interpreting the growth of the Atchafalaya River or predicting its behavior.

Development of the Atchafalaya Distributary

Although the Atchafalaya River is serving as a distributary of the Mississippi and is diverting flow from the river at an increasingly rapid rate, it is difficult to compare it with other streams which have in the past diverted the river. It is doubtful that the Atchafalaya would ever have become a distributary of consequence if it had been allowed to develop under natural conditions. The earliest records show the channel to have been plugged with a raft of logs for many miles downstream from the head. The removal of this raft and dredging of the connection with the Mississippi (Old River) were in large measure directly responsible for early enlargement of the stream. Subsequent dredging in the Grand Lake area and at other places along its channel was needed to create and maintain a navigable channel. These activities have also accelerated enlarging processes.

Artificial levees constructed close to the banks in the upper reaches of the stream have contained overbank flow and promoted channel scouring. Railroad and highway embankments, canals, and flood control levees in the region have served to confine the river flow to a few outlets; whereas, under natural conditions, numerous channels were available for distribution of floodwaters.

There are other conditions which make it difficult to compare the Atchafalaya River with natural diversion channels. The downstream angle of diversion of the Mississippi and Old Rivers was obtuse prior to the Carr Point Cutoff in 1944. Studies of former diversions of the Mississippi and the development of deltaic distributaries show that diversions are brought about only by channels which leave the main stream with an acute downstream angle. There still remains an obtuse angle between the thread of the Mississippi current and Old River and, were this not the case, discharge down the Atchafalaya might be considerably increased.

Although actively enlarging, the Atchafalaya has shown little tendency to meander, and, as a matter of fact, it appears to have been straightening its course recently as the discharge increased. It has behaved similarly to deltaic distributaries in this regard.

Grand Lake and associated lakes occupy the lowest part of the Atchafalaya Basin. The lakes act as a base level to the Atchafalaya River in the same way that the sea has served as a base level for the Mississippi River. Under natural conditions the lake system, which is near sea level, served as a stilling basin and floodwaters found an outlet in several minor streams which entered Bayou Teche and discharged by way of the Lower Atchafalaya River. A levee system now rims the entire basin. Flood stages have been greatly raised, and the stilling basin effects are even more pronounced. Under natural conditions, the Atchafalaya discharged into a network of bayous at the head of Grand Lake and deep scouring of a single channel did not occur. Confinement of water by artificial levees has concentrated the discharge into fewer channels, and in places has forced the river to behave as a single seaward-lengthening, widening, and deepening distributary. Abnormal flood stages set up by the artificial levees around the Atchafalaya Basin have permitted the development of abnormally high natural levees in the lower reaches of the river which further concentrate the flow and thereby promote channel deepening.

The critical period in the enlargement of the Atchafalaya should occur when the river is able to take full advantage of its shorter course to the sea by establishing a single channel from its head to Atchafalaya Bay. The river then should be able to discharge an increasingly greater volume into the Gulf during ordinary stages, leading to a rapid increase in diversion of the Mississippi River.

PART VI: SUMMARY AND CONCLUSIONS

Former Mississippi River Diversions

Several diversions of the Mississippi River have occurred during very recent geological time. Bayou Teche, which flanks the western side of the Atchafalaya Basin, marks a former course which was abandoned for a course which is now followed partly by the modern Mississippi River and partly by Bayou Lafourche. The Lafourche-Mississippi course was in turn abandoned at Donaldsonville, Louisiana, in favor of the present course to the sea. This last diversion has been dated as occurring approximately 1000 years ago. In each instance, the river abandoned a long-occupied channel and flowed down a lowland which offered a gradient advantage. The Atchafalaya River flows in an interlevee lowland similar in many respects to those followed by former Mississippi River diversions and thus furnishes an ideal path along which the Mississippi River can steepen its gradient and shorten its course to the Gulf. A study of former diversions of the Mississippi River does not, however, afford a true parallel, in that none of the former diversions discharged into an inland lake as does the Atchafalaya. This difference will be eliminated when the growth of the Atchafalaya delta has filled in the Grand Lake area and a single channel is established from the head of the Atchafalaya River to the sea.

Bed and Banks and Their Influence on Channel Enlargement

The bed and banks of the Atchafalaya River are composed of two distinct units: a loose, sandy substratum, and a finer-grained, more cohesive topstratum. The topstratum, in turn, consists of several types of materials which offer varying degrees of resistance to channel enlargement. For study purposes, the leveed section of the Atchafalaya River was divided into eight reaches, based on the type of materials forming the bed and banks. The growth and development of cross-sectional areas along ranges in each of these reaches were compared. It was found that one of these reaches, between River Miles 14.5 and 15.5, prior to the middle 1930's resisted channel growth to a marked degree and in so doing acted as one of the controls to over-all channel enlargement. The bed and banks in this reach are composed of tough channel-fill clays extending to depths greater than the present channel. An increased rate of enlargement in this reach, beginning about 1933, suggests that it may have ceased to function as a control reach, and that now the principal control to channel enlargement is an extensive reach between River Miles 20.5 and 46.5. The bed and banks of this reach are composed principally of backswamp clays which in a number of places have been scoured through to substratum sands.

If the only factor influencing channel enlargement were the composition of the bed and banks, there would be little reason to believe that future channel enlargement would proceed less rapidly than it has in the past. In fact, bank caving and consequent channel enlargement should be accelerated as the channel continues to deepen and cuts more and more into substratum sands. In short, the controlling effect of cohesive materials in the bed and banks is diminishing as discharge increases.

Channel Development in the Leveed Section of the River

The constantly increasing trend of Atchafalaya River channel enlargement is amply documented by hydrographic surveys covering a long span of years. The trend manifests itself along many reaches of the present river by caving of opposite banks, a condition not observed on the Mississippi River where caving along an individual reach is usually confined to a single bank. Together with over-all enlargement, several significant developments are taking place in the channel. Surveys show that the average channel depth is increasing, that the channel is widening, and that the river is straightening its course. Older surveys show deep, wide holes in the channel and in narrow, shallow reaches. These irregularities are being smoothed out as the channel enlarges and the river develops a more even thalweg profile.

It is evident that the stream has not established equilibrium between its volume, slope, load, and the materials composing its bed and banks, and that the stream is constantly adjusting itself to increased discharge. The straightening of its course and smoothing of its bed have increased the ability of the leveed section of the river to carry water to the lower reaches.

Sedimentation in the Atchafalaya Delta

The sediments which form the Atchafalaya delta and are rapidly filling Grand Lake show a gradual increase in coarseness from bottom to top. The earliest filling of Grand Lake is composed of clay and silty clay with a red-brown color which indicates its Red River origin. Later deposition is represented by brown and gray sandy silts and silty sands showing the increasing influence of diversion of Mississippi River water into the Atchafalaya. The source of the major portion of the present deltaic deposits is the suspended load carried by the Atchafalaya River.

Comparison of bed-load samples of the Atchafalaya and Mississippi Rivers shows that only small quantities of bed load are introduced from the Mississippi into the Atchafalaya River, even at high stages. Further studies are necessary to determine if the angle of diversion between the Mississippi and Old Rivers and the difference in elevation of the channel bottoms of the two streams near the point of diversion have an effect on the amount of Mississippi River bed load being diverted. The difference in channel-bottom elevations at the point of diversion may have the effect of a "skimming weir" which selects the fines and carries them down the Atchafalaya but leaves the coarse material behind. This effect should be minimized when the difference in channel-bottom elevation at the diversion point is reduced, and considerable portions of coarse bed load from the Mississippi River should then be carried down the Atchafalaya to increase the rate of delta-building in Grand Lake.

Predictions as to Date of Diversion

Present studies do not permit a prediction as to the date when the Mississippi will be finally diverted. However, the following generalizations may have a bearing on interpretations of the time of complete diversion.

Older diversions of the Mississippi show that capture of the river was first a slow process until the main discharge followed the diversion arm, then rapid deterioration of the older channel set in. Although the Atchafalaya discharge is increasing at a rapid rate, there is little indication that a stage when rapid deterioration of the main channel begins has been reached. However, it is believed that when signs of deterioration are unmistakable in the Mississippi River channel below Old River, rapid diversion will be in process or the diversion arm will have become the main channel. The implication of the preceding statement is that when this stage in development of the diversion is reached, the stage when rapid deterioration in the Mississippi River channel below Old River is unmistakable, the difficulties of controlling it would be greatly increased if not made impossible.

The present inability of the Atchafalaya to discharge its flow directly into the Gulf is an obstacle to rapid enlargement of the stream. Water now introduced at the head of Grand Lake is impounded, raising the level of the lake during high stages, and exerting a backwater effect on the lower reaches of the river. Once the river ceases to dissipate its discharge at the head of Grand Lake and can concentrate its flow in a single channel to the Gulf, the full advantage of a direct gradient from the head to the mouth can be realized. A rapid increase in Mississippi River diversion should result. Complete data are not available for verification of the above thesis; however, this is the process of creation of active distributaries in the modern delta. Should further investigation show a correlation between the building of the Atchafalaya delta and the increasing rate of discharge, extrapolation from records of sedimentation in Grand Lake may permit the prediction of a fairly accurate date for establishment of a channel to the head of the Lower Atchafalaya River. This date would be a critical one in the history of the diversion of the Mississippi River.

Comparison of the cross-sectional enlargement of the Atchafalaya River channel with annual discharges of the Mississippi River emphasizes the marked effect of high discharge years on channel enlargement. In this connection, it should be borne in mind that several consecutive years of high annual discharge may critically increase the rate of channel enlargement. Therefore, predictions of the future behavior of the Atchafalaya River based on the average annual discharges may be overly conservative.

Flood Control and Navigation

Unless a channel is maintained in the lower Atchafalaya Basin, flood stages will increase in the leveed section of the river, and the use of the unleveed portion of the Atchafalaya River as an artery of navigation will cease in a very short time. Continued channel maintenance, on the other hand, is probably the most efficient method of speeding up Atchafalaya River discharge and eventual capture of the Mississippi. This conflict between natural development and local interests is perhaps as valid a reason as can be offered for immediate control of diversion.

PART VII: RECOMMENDATIONS

Geological studies to date support the view that the Atchafalaya will continue to enlarge until it captures the Mississippi. There is no sign of diminishing rate of channel enlargement and if corrective measures are planned it is recommended that they be undertaken as soon as possible. It is further believed that measures involving direct control of Mississippi River discharge into the Atchafalaya Basin are preferable to partial measures.

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APPENDIX B

ENGINEERING FACTUAL DATA

PREPARED BY

NEW ORLEANS DISTRICT

FOR

MISSISSIPPI RIVER COMMISSION

CORPS OF ENGINEERS, U. S. ARMY

VICKSBURG, MISSISSIPPI

CONTENTS

CONTENTS

APPENDIX B

ENGINEERING FACTUAL DATA

Location of Study and Tributary Areas

Location

The study area is located in the central southern part of Louisiana, extending from the vicinities of the confluences of the Old and Mississippi Rivers and of the Old, Red, and Atchafalaya Rivers to the Gulf of Mexico. The location and relation of this area to the Mississippi River and Tributary Basins is shown on Plate B1, "General Map and Tributary Area." Lower Mississippi Valley Division and District boundaries and other pertinent data are shown on Plate B2, "Division Map."

Tributary areas

Areas tributary to the Lower Mississippi, Old and Atchafalaya Rivers comprise about 1,245,000 square miles, or approximately 41 percent of the area of the continental United States, and are located generally between the Appalachian Mountains on the east and the Rocky Mountains on the west, and include all or parts of 31 states and 2 Canadian provinces. The major tributary streams entering the study area are the Red and its tributary, Ouachita-Black Rivers, which have areas of 66,000 square miles, excluding the Ouachita-Black Basins, and 26,000 square miles, respectively, and waters diverted from the Mississippi River through Old River.

Data pertinent to the Lower Mississippi River, Cairo, Illinois, to the Gulf of Mexico, are shown on Plates B3 through B6: "Profile of the Mississippi River Showing 1927 and 1937 High Water, 1936 Low Water, 1943 Channel and Class of Material Found along Thalweg"; "Bridges"; "Principal Locks, Contiguous to the Mississippi River"; and "Distances between Points along the Mississippi River in River Miles."

Data Pertinent to the Problem

Surveys

Information and data derived from a great number of surveys made by the Corps of Engineers have been used in this study. Some of these, such as land plats showing bank lines of the Red, Mississippi, Old and Atchafalaya Rivers, and Atchafalaya Basin, date as far back as 1808, whereas other more recent hydrographic and planimetric surveys were made in the latter part of 1950 and the early part of 1951 specifically to enhance existing records.

A compilation of hydrographic and planimetric surveys used in conjunction with the preparation of this study is shown in Table 1*, "Hydrographic Surveys."

Locations and coverages of 1:20,000 plan maps are outlined on Plate B7, "Index to Plan Maps." Surveys and other pertinent engineering data are presented in plan, profile and typical comparative sections on Plates B8 through B36, "Plan, Profile and Sections, Red River below Acme, La., Mississippi River in Vicinity of Old River Junction, Old and Atchafalaya Rivers, Atchafalaya Basin and Outlets." Distances between points along the Atchafalaya River and main channel are shown on Plate B102.

Levee profiles and flow lines of the East and West Atchafalaya Basin Protection Levees below the latitude of Krotz Springs, La., are shown on Plate B37.

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* Tables referred to in this appendix may be found in volume 3 of this report.

Pertinent hydrologic and hydrographic data are included in the condensed profiles shown on Plate B38, "Red and Atchafalaya Rivers, Atchafalaya Basin Main Channel and Lower Atchafalaya River, Acme, La., to the Gulf of Mexico."

A historical presentation of the natural development of Old River and vicinity is demonstrated on Plate B78, "Relationship of Old, Red, Atchafalaya and Mississippi Rivers, 1805-1950."

Aerial photographs

The entire area under consideration in this study has been photographed within the past twenty years, and a tabulation of the various sections and dates of aerial coverage of the various floodways is shown on Plate B39, "Aerial Photograph Coverage, 1930-1950."

Hydrologic

Climate. Average annual temperature over the Atchafalaya Basin based on long-term records (58 years or more) of Weather Bureau Stations in Louisiana at Baton Rouge, Cheneyville, Donaldsonville, Franklin, Grand Coteau, Houma, Lafayette and Melville is about 68°F and monthly averages vary from 82°F in July to 53°F in January. Extremes of 110°F and 2°F have been recorded at Baton Rouge. A minimum of 2°F has also been recorded at Grand Coteau.

Average annual precipitation over the basin is 58 inches, maximum of 83 inches in 1905, and minimum of 38 inches in 1924. Monthly averages ranged from 7.0 inches in July to 3.4 inches in October. Maximum annual station rainfall of 111.3 inches occurred at Morgan City in 1946 and a minimum of 31.8 inches occurred at Grand Coteau in 1924. Maximum monthly station rainfall was 38.0 inches in August 1940 at Lafayette, and minimum monthly precipitation was zero on various occasions at several stations. The period of record of precipitation stations in and adjacent to the Atchafalaya Basin is shown in Table 2, and their location is shown on Plate B40, "Hydrologic Stations."

Stream flow:

Discharge. The earliest measurements of discharge were made in 1851 on the Mississippi River at Red River Landing, on Old River at Torras, and on the Atchafalaya River near its head. Observations have been made intermittently at major river stations since 1880, while from 1928 to date daily discharge amounts are available as derived from daily gage readings and systematic regular discharge measurements. Maximum of record are 1,536,000 c.f.s. at Red River Landing in 1945, 1,977,000 c.f.s. at Tarbert's Landing in 1937, 514,000 c.f.s. at Torras in 1937, and 661,000 c.f.s. at Simmesport in 1945. An observation of 1,595,000 c.f.s. was made in 1882 at Red River Landing; however, accuracy of this observation was influenced by crevasses as well as the method of observation. Periods of record and locations of discharge measurements at regular stations pertinent to the study area are shown in Table 3, "Discharge Records," and on Plate B40, "Hydrologic Stations." Rating curves for principal gaging stations in the study area, comparing the stage-discharge relations over the years of record, are presented on Plates B41 through B50, "Stage-Discharge Relation."

Earliest discharge observations in the Lower Atchafalaya River were made at Morgan City during the flood of 1927. Since this date intermittent observations have been made. The maximum observed discharge of 703,000 second-feet occurred in 1927.

Measurement of Wax Lake Outlet discharge at Calumet began in 1942.

Approximately 20 percent of Atchafalaya River flow is diverted through this channel. Maximum discharge observed was 132,000 second-feet in 1950. A tabulation of maximum and minimum stages and discharge is presented in Table 4.

Locations of the above discharge ranges are shown on Plate B40, "Hydrologic Stations."

Sufficient measurements of flow in the Atchafalaya Basin and Outlets were made from 1935 to date to determine the distribution of flood flow within the basin. These measurements were made on all main tributaries or channels below the main Atchafalaya River levees. Results of the 1937, 1945, and 1950 observations are presented on Plates B51 through B53, "Hydraulic Characteristics."

Maximum and minimum discharge of principal Mississippi River stations for that reach extending from St. Louis, Missouri, to Baton Rouge, Louisiana, are shown in Table 5.

Stage. Gage records have been kept regularly for many years at a number of locations. Observations of the Mississippi River at Red River Landing began in 1871 and have been continuous to date except for the period 1923-1940 when the gage was located across the river at Angola on the left bank and a short distance upstream from the present location. A maximum stage of 56.40 feet on the Red River Landing gage occurred in 1945 while a maximum of 57.45 was experienced on the Angola gage in 1927.

Records for Lower Old River at Torras began in 1903 and the maximum stage recorded was 60.5 ft. in 1927. On the Atchafalaya River four major stations have long periods of record with maximum gage readings recorded during the 1927 flood, as follows: Barbre Landing readings began in 1880 with a maximum of 57.7 ft.; Simmesport, 1900 and 53.4 ft.; Melville, 1885 and 46.8 ft.; and Krotz Springs (Missouri Pacific Railroad bridge), 1912 and 58.5 ft. Additional records for all principal gaging stations in the study area are given in Table 6, "Maximum and Minimum Recorded Stages on Principal Gaging Stations."

Special gages are read during flood and extreme low-water seasons on the Atchafalaya River and main channel and along the guide levees and secondary channels during high water. Readings made during the high waters of 1937, 1945 and 1950 are plotted on Plates B8 through B29, "Plan, Profile and Stations"; Plates B31, B37 and B38, "Profiles"; and Plates B51 through B53, "Hydraulic Characteristics." Stages of the 1945 and 1950 high waters are shown on Plates B35 and B36, "Plan, Profile and Sections."

A summary of available gage records in the study area is given in Table 7, "Gage Records," and location of stations is shown on Plate B40, "Hydrologic Stations."

Highest annual stages of principal Mississippi River stations from Cairo, Illinois, to the Gulf of Mexico are listed in Table 8; highest annual stages of Red, Black, Old and Atchafalaya Rivers, and the Atchafalaya Basin and Outlets are shown in Table 9.

Suspended load, bed materials and deposited sediment. Suspended sediment and river bed samples in the Mississippi, Red, Old and Atchafalaya Rivers and the outlets to the Gulf were secured and analyzed in 1950-1951 to determine the amount and character of suspended sediment transported into and out of the Atchafalaya Basin, the relative contributive factor of the Red, Mississippi, Old and Atchafalaya Rivers to the load, the amount and nature of material deposited in the Atchafalaya Basin and its relation to the suspended load, and, finally, to determine any progressive changes in deposits that have taken, or are taking place, within the Atchafalaya Basin.

Locations of suspended sediment and discharge stations, sedimentation ranges, bed-material sampling points, and limits of reaches for main river channel studies are shown on Plate B54, "Hydrographic Reaches, Sedimentation Ranges, and Suspended Sediment and Bed Material Stations."

Suspended sediment. Suspended sediment samples were secured at stages selected to represent various flow conditions over the range of stages experienced during the November 1950 through February 1951 survey. Where practicable, point-integrated samples were secured at locations in the stream as determined by the Luby method. In this procedure, sampling points were selected at centroids of equal areas of discharge, essentially as described in the Federal Inter-Agency River Basin Committee Report No. 1, "Field Practice and Equipment used in Sampling Suspended Sediment." This method requires either an assumed velocity distribution or a distribution curve based on velocity measurements. Since tidal effects in Berwick Bay and Wax Lake Outlet preclude the making of rational discharge ratings, an arbitrary method of determining sampling points was employed at these stations. Points were also selected arbitrarily on the Red River at Alexandria, Louisiana, where the collection of samples was primarily for the purpose of grain-size and mineral analysis. Travel time of the water flow was computed so that sampling could be performed essentially on the same water as it passed each sampling point.

The suspended sediment samples were analyzed by the New Orleans District Laboratory for total sediment concentrations, grain size, and salinity. When necessary, due to light concentrations, a number of samples in the vertical were combined for grain-size analysis. Results of laboratory analyses are shown in Tables 10 through 17.

Pertinent data on the suspended sediment observations are given in Table 18.

Results of suspended sediment observations of the Mississippi River at Baton Rouge, Louisiana, are shown on Plate B101.

River bed material. Thirty-eight thalweg bed-material samples were secured in 1951 in the Red, Mississippi, Old, and Atchafalaya Rivers and in the main channels of the Atchafalaya Basin. Where possible, these samples were taken from the same locations from which bed material was obtained in the 1932 study of river bed material. The results of the 1932 survey were published in January 1935 by the Waterways Experiment Station in Table 42 of Paper No. 17, "Studies of River Bed Materials and Their Movement, with Special Reference to the Lower Mississippi River."

Mechanical analyses, specific gravity, and other physical data determination of the 1951 bed-material samples followed the same procedure employed in the 1932 work. For purposes of comparison, results of analyses of 1932 samples falling within the present leveed portion of the Atchafalaya Basin are given in Table 19, "Physical Data and Various Constants of 1932 Bed Material Samples," and Table 20, "Studies of River Bed Material, 1932 Samples." Results of 1951 samples are given in Table 21, "Physical Data and Various Constants of 1951 Bed Material Samples," and Table 22, "Studies of River Bed Material, 1951 Samples."

Deposited sediment. For studies of progressive changes in the Atchafalaya Basin, the following surveys of sedimentation ranges are available for comparison:

Atchafalaya Basin	Ranges 1-18, surveys of 1932, 1935, and 1950;
Grand Lake	Ranges 18A-22, surveys of 1934, 1940, 1941 and 1950-51.
Six Mile Lake	Ranges 23-25, surveys of 1941 and 1950.

Ground surface elevations determined from these surveys are shown in comparative sections on Plates B55 through B73, "Sedimentation Ranges."

Employing the 1932, 1934, and 1941 surveys as datums in the Atchafalaya Basin above Grand Lake, in Grand Lake, and in Six Mile Lake regions, respectively, average heights and limits of fill as of 1950-1951 conditions are shown in plan on Plate B74, "Lower Atchafalaya Basin, Height of Fill, 1932-1950."

Accretion in Grand and Six Mile Lakes of the Lower Atchafalaya Basin, represented pictorally in plan from low-water season aerial photographs, is shown on Plate B75, "Lower Atchafalaya Basin, Accretion, Grand and Six Mile Lakes, 1917-1950."

Indications of overbank deposits in the leveed section of the Atchafalaya River from Mile 0 to Mile 53.4 (1950 survey), on the basis of 1916-1917 and 1950 surveys, are shown in Plan, Profile and Sections, Plates B15 through B21, inclusive.

Tides. Records from the automatic tide gage located on the east side of Eugene Island in Atchafalaya Bay (see Plate 40, "Hydrologic Stations") are available from 26 May 1939 to date.

Table 23, "Tidal Effects in Lower Atchafalaya Basin," is a tabulation of data obtained from a study of available records of gages located in the Lower Atchafalaya Basin.

Salinity. Locations and periods of records of water sampling stations, operated primarily to determine salinity concentrations in parts per million of chlorine in the Lower Atchafalaya Basin and adjacent coastal areas, are shown on Plate B40, "Hydrologic Stations," and in Table 24, "Period of Record of Salinity Stations," respectively.

The relationship of salinity in the Lower Atchafalaya Basin to stages at Simmesport, Louisiana, for the years 1939 to 1942 and 1947 to 1950, inclusive, is shown on Plate B76, "Salinity in Lower Atchafalaya Basin and Stages at Simmesport, La."

Floods of record. A great number of floods of considerable magnitude have occurred on the Atchafalaya River as evidenced by records for the period 1882-1950 and shown in Table 25, "Record of Atchafalaya River Floods at Simmesport, La." Foremost among these on which a large volume of information is readily available are the floods of 1927, 1937, 1945 and 1950.

Relationship between the discharges in the Atchafalaya River at Simmesport, the Mississippi River at Red River and Tarbert Landing and the Red River at Acme in these four years is shown in Table 26, "Elements of Discharge at Simmesport and Red River Landing."

Numerous crevasses occurred in the Atchafalaya River levees during the earlier floods, with the frequency of occurrence rapidly diminishing as the controlling levees were strengthened. Table 27 contains data on "Crevasses of the Atchafalaya River Levees."

Project flood. The engineering plan for flood control in the Lower Mississippi Valley, as adopted by the Act of 15 May 1928 and subsequent amendments, is based on protection against a so-called project or design flood approximately 20 percent greater in magnitude in the lower river than the maximum flood of record in 1927. The distribution of flow for the design flood among the several major tributaries and outlets is shown on Plate B77.

Flood control improvements

Atchafalaya River levees. With the creation of the Mississippi River Commission by the Act of 28 June 1879, the Federal Government became an active agent in the control of the Mississippi River and a new period of levee development began for the Lower Mississippi Valley.

The Act of 22 September 1922 extended the jurisdiction of the Mississippi River Commission to the tributaries and outlets of the Lower Mississippi River below Cairo, Illinois, insofar as these tributaries and outlets are affected by the floodwaters of the Mississippi River.

As a result of the great flood of 1927, the second Flood Control Act of 15 May 1928 was passed, providing authorization for the construction and maintenance of levees along both banks of the Atchafalaya River.

Originally constructed by the State of Louisiana to grades based on the 1912 and later the 1922 floods, the Atchafalaya River levees were subsequently strengthened and rebuilt by the Corps of Engineers to follow the original irregular profile as closely as practicable and finally extend southward to a distance of 55 miles from the head of the Atchafalaya River on the east bank and 67 miles on the west bank.

Progress of this levee construction during the period 1881-1950 is shown in Table 29, "Atchafalaya River Levees."

Sill dams. To control and stabilize the river discharge down the Red and Atchafalaya Rivers, the President of the Mississippi River Commission, on 21 August 1886, set up a project for the expenditure of $187,500 for "Rectification of the Red and Atchafalaya Rivers." This plan set aside $15,000 for maintenance of Lower Old River and called for the purchase of plant necessary for construction of a series of sill dams in the Atchafalaya River, with the uppermost just below Bayou des Glaises and the others at intervals not exceeding one-quarter of a mile. Six sills were indicated on the original plans, but only two of these were built in the Atchafalaya River and one in the Red River. See Plates B16 and B8, respectively, for locations.

Red River sill dam. In connection with the over-all project set up by the Mississippi River Commission, a sill and dam were built across the Red River from the west shore of Turnbull's Island westwardly to the mainland and between the mouth of Red River and the head of the Atchafalaya River. The crest of this dam was to have a suitable elevation above the observations in Upper Old River, its object being to force the Red River, when below a certain low stage, to flow through Upper Old River and discharge into the Mississippi River. Built to an elevation of approximately 6.8 feet m.s.l. in 1891, this dam gradually deteriorated, was reported to be in bad condition in 1895, and appears to have been abandoned in 1896.

Atchafalaya River Sill Dam No. 1. Work was begun on Sill No. 1, 500 feet below the mouth of Bayou des Glaises at the present location of the highway and railroad bridge at Simmesport, La., in 1887. Sills were laid 304 feet long, 3 feet thick and 75 feet wide with 5-foot overlap. About 100 tons of rock were required to sink a mattress and with the 350 tons placed later, an average of 42 pounds per square foot. Connection with the left bank levee was secured by three earthen sodded spurs with horizontal crests. Connection with the right bank levee was secured by two earthen sloping spurs paved with 6 inches of stone. Estimated cost of the sill was $34,546. Work on the dam at Sill No. 1 was begun 7 November 1888 and completed 21 December 1888. Built of successive layers of hard clay, gravel, and willow mattresses, the upstream edge of the dam was placed 20 feet below the downstream edge of the sill. Two entire courses of mattress and a portion of a third extending out from each bank were sunk, all 3 feet thick, and with respective widths of 100, 66 and 30 feet. The dam was built up to within 6 feet of low-water mark, with a heavy covering of rock placed on top. Final maintenance of this dam by the United States was performed in 1920, at which time a mattress was sunk renewing one-half of the apron on the upper side of the dam on the left bank. Subsequent maintenance has been performed by the Louisiana and Arkansas Railroad Company. Comparative sections taken at the site of this dam throughout the period 1880-1950 are shown on Plate B82, "Sill Dam No. 1, Mile 4.9." Comparative cross-sectional areas are given in Table 30, "Comparison of Areas over Sill Dam No. 1, Period 1880-1951."

Atchafalaya River Sill Dam No. 3. Work was begun on Sill No. 3, 26 November 1888. With its upper edge 1750 feet downstream from the lower edge of Sill No. 1, the sill was constructed of mattresses 3 feet thick, 304 feet wide, and covered with a heavy layer of rock. Two spur embankments were built connecting the sill to the levee on the right bank, and with the old left bank levee having caved into the river, a new one was built around the end of the sill. The levee and embankments at the end of the mattress were paved with rock and the sill and dam were completed 27 August 1889. The mattresses were so proportioned as to give the dam, when completed, side slopes of one on three and crown width of 30 feet. Final maintenance of this dam by the United States was performed in 1920, at which time mattresses were sunk renewing one-half of the apron on the upper side of the dam along the left bank, others renewing the apron on the lower side of the dam, and still others renewing the lower one-half and the upstream left bank one-fourth of the sill. Soundings over Sill Dam No. 3 in 1948 showed -25 feet m.s.l. which indicate that the remains of the old sill are preventing a -50 foot m.s.l. pool just below the bridge from connecting with a -76 foot m.s.l. pool one-half mile below the bridge.

Floodways, including structures. The Atchafalaya Basin Floodway was authorized by the Flood Control Act dated 15 May 1928, with subsequent amendments of 1936, 1938, 1941, and 1944, and provides for diversion of excess floodwaters from the Mississippi River in the vicinity of its junction with Old River. These diverted flows will pass through the Morganza Floodway, Atchafalaya River and West Atchafalaya Floodway, joining below the latitude of Krotz Springs, then will be carried between the guide levees through the Atchafalaya Basin Floodway, thence by way of Wax Lake Outlet and the Lower Atchafalaya River to the Gulf. Distribution of the project flood is shown on Plate B77, "Mississippi River and Tributaries, Distribution of Project Floods." An index to utility and bridge crossings of the river and floodways is developed on Plate B79.

Morganza Floodway. The Morganza Floodway is a leveed floodway extending approximately 20 miles from the Mississippi River, in the vicinity of Mile 280 A.H.P., about 21 miles below the mouth of Old River, to the latitude of Krotz Springs, Louisiana, that encompasses an area of about 105 square miles. Floodwaters will enter the floodway through the Morganza Control Structure at its head near Morganza, La., and will be confined between the Upper Morganza Guide Levee and the East Atchafalaya River levee on the north and west and the Lower Morganza Guide Levee and the East Atchafalaya Basin Protection Levee on the south and east.

One railroad and one highway crossing will be provided by the combined Morganza Control Structure. Three additional high-level crossings have been provided for the main line Texas and Pacific Railroad through Melville, for the N.O.T. & M. Railroad and for U. S. Highway 190 through Krotz Springs.

Atchafalaya River. The source of the Atchafalaya River is at the confluence of the Red and Lower Old Rivers about 5 miles easterly from Simmesport, La. The Atchafalaya River carries practically all of the flow from the Red River, serves as a distributary of the Mississippi River, and intermittently carries additional flow from Bayou des Glaises in the vicinity of Simmesport, La. Flowing in a southerly direction between the East and West Atchafalaya River levees for about 54.3 miles, the river loses its identity as such below the ends of the levees and thence flows to the latitude of Morgan

City, La., through bayous and lakes. Progress of construction of the East and West Atchafalaya River levees during the period 1881-1950 is shown in Table 29, "Atchafalaya River Levees." Plans and elevations of bridges over Old and Atchafalaya Rivers are shown on Plates B80 and B81.

West Atchafalaya Floodway. The West Atchafalaya Floodway is a leveed floodway extending approximately 33 miles from the Bayou des Glaises levee between Simmesport and Hamburg, Louisiana, to the latitude of Krotz Springs, La., encompassing about 260 square miles of which the lower part is subject to backwater from the Atchafalaya Basin. Floodwaters from the Red River backwater area or from the Atchafalaya River may enter the floodway by overtopping the Bayou des Glaises fuse plug levee at the head of the spillway. The two principal towns in the floodway, Simmesport and Melville, are protected by ring levees. Construction of the high-level railroad crossing for the N.O.T. & M. Railroad is under way and a high-level crossing for U. S. Highway 190 is to be provided.

Atchafalaya Basin Floodway. The Atchafalaya Basin Floodway extends from the southern limits of the West Atchafalaya and Morganza Floodways at about the latitude of the lower limits of the town of Krotz Springs, La., to Morgan City, La. It receives the discharge of the Atchafalaya River and the flood flows of the Morganza and West Atchafalaya Floodways which are then carried between the East and West Atchafalaya Basin Protection Levees to the Lower Atchafalaya River at Morgan City, La., and Wax Lake Outlet located approximately 10 miles west of Morgan City. Protection for Berwick and Morgan City has been provided by the construction of floodwalls. Locations of the completed structures, together with levee gaps closed during the period 1933 to 1951, are shown on Plate B84, "Structures and Levee Openings."

Wax Lake Outlet. The Overton Act of 1936 provided for "the construction of an additional outlet to the Gulf of Mexico, west of Berwick, La." As shown on Plates B35 and B36, "Plan, Profile and Sections," the dredged outlet extends from Six Mile Lake across the Teche ridge at Calumet, La., into Atchafalaya Bay, a distance of approximately 15.7 miles, crossing Bayou Teche, the Intracoastal Waterway-Gulf Section and Wax Lake Pass. The outlet is crossed near Calumet by U. S. Highway 90, the main line of the Southern Pacific Railroad and other public utilities constructed at the expense of the United States. See Plate B81 for plan and elevation of bridges. Dredged to a uniform depth of 45 feet below m.s.l., the outlet channel has a bottom width of 300 feet from Six Mile Lake to a point about 1/2 mile below Bayou Teche, where it widens to 400 feet and maintains this width to Atchafalaya Bay. Completed in October 1941, the outlet passed 130,000 c.f.s. during the 1945 flood and has a design capacity at project flood stage of 270,000 c.f.s. The guide levees on either side of the outlet, about 2,000 feet apart near Bayou Teche and about 10,000 feet at their lower ends, tie into the West Atchafalaya Basin Protection Levee and extend to the vicinity of the Intracoastal Waterway where they connect with levees built along the upper (north) side of that canal. No levees were built below the Intracoastal Waterway but the dredged material has been deposited in spoil banks, with openings left for cross drainage. The levee crossings over Bayou Teche are provided with floodgates, one on either side to provide for a navigable crossing during low-water and moderate flood stages. These flood gates were completed 14 April 1950.

Channel enlargement and dikes. As mentioned previously, the Atchafalaya River proper is leveed on both banks from its head to about Mile 55. A short distance below the effects of this confinement, the river loses its identity and deteriorates into a number of small streams meandering over a wide area of the lower basin and ultimately emptying into Grand and Six Mile Lakes. Development of a main flood-carrying channel through this reach of the basin was undertaken during the early 1930's. A channel, known as the Atchafalaya Basin main channel, was excavated from the Atchafalaya River at about Mile 55 following a general route along the center of the floodway between the guide levees. Over a period of about 10 years this channel was extended to Myette Point in Grand Lake about Mile 97. Spoil from these excavations was placed in a manner to promote confinement of the ordinary flow and development of the channel. Other dredging work was done along the leveed portion of the Atchafalaya River at restricted reaches to assist in development of an efficient channel. This work was done under provisions of the 15 June 1936 Act which provides for

> "...improvement of the discharge capacity of the leveed channel of the Atchafalaya River and of its outlets, including the enlargement of the openings of existing railroad and highway bridges across the Atchafalaya River and such alterations of existing crossings of the river as are deemed necessary to the execution of the plan, and the enlargement of other restricted sections of the channel."

Locations, dates and quantities of excavations along these lines are shown on Plate B83.

Navigation improvements

The initial project for navigation on Old River was a feature of the project, "Red River below Fulton, Arkansas," adopted by the Act approved 13 July 1892, and provided for improvement from Fulton to the Mississippi River by clearing, snagging, dredging shoals, building levees either alone or in cooperation with riparian states, closing outlets, revetting caving banks and preventing injurious cutoffs. The existing project for 9 feet by 100 feet is a feature of the Overton-Red River Waterway providing navigation from the Mississippi River to Shreveport which was adopted by the River and Harbor Act of 24 July 1946.

The first improvement of the Atchafalaya River in the interest of navigation was the removal of the large drift jam that blocked its upper reaches at the time of the first white settlement. The work of removing this jam was undertaken by the State of Louisiana commencing in 1840 and continuing intermittently until 1861. This opened a pilot channel which subsequently enlarged to its present size as a result primarily of river action. There is no existing Federal project for navigation on the Atchafalaya River. Although ample widths and depths are available from its head to Grand Lake, at all stages the route through Grand Lake and Six Mile Lake to Berwick Bay at Morgan City is shallow with controlling depths of about 5 feet at low water. A project for improving this reach to 12- by 125-foot dimensions at low water has been reported favorably in the "Review of Reports on Atchafalaya River, Morgan City to Mississippi River via Old River" dated 6 September 1950.

The existing navigation project, "Atchafalaya River, Morgan City to the Gulf of Mexico," was adopted by the River and Harbor Act of 25 June 1910 and provides for a channel 20 feet in depth over a bottom width of 200 feet, extending from the 20-foot contour below mean low water (mean low Gulf level) in the Atchafalaya Bay to the same contour in the Gulf of Mexico, and for its maintenance for a period of three years. Work on the enlargement of the channel started 13 August 1910 and was completed 14 October 1911. Maintenance dredging was performed in 1916, 1919, 1939 and 1947. Since 1914 no attempt has been made to maintain project dimensions. In 1947, maintenance dredging was performed to restore a 10- by 100-foot channel at the mouth of the Atchafalaya River, vicinity of Eugene Island, between Atchafalaya Bay and the Gulf of Mexico, a distance of 8 miles. See Plate B29 for pertinent data.

From Texas, the Intracoastal Waterway skirts the Louisiana coast, crossing the Atchafalaya River south of Morgan City. It crosses the Mississippi River through the Harvey and Industrial Canal Locks in the port of New Orleans, and continues to Florida. The Plaquemine-Morgan City Alternate Route of the Intracoastal Waterway connects the Mississippi at Plaquemine Lock to the waterway at Morgan City. Its existing dimensions are 9 feet by 100 feet. The alternate route crosses the East Atchafalaya Basin Protection Levee through the Bayou Sorrell Lock about 12 miles from Plaquemine. The River and Harbor Act approved 24 July 1946 authorized enlargement of the alternate route to dimensions of 12 feet by 125 feet, with a northward extension of the same size to Port Allen and a lock there for entrance to the Mississippi River. See Plate B1.

Navigation on the Intracoastal Waterway Gulf Section through the extension of the East Protection Levee below Morgan City, La., will be provided by the Bayou Boeuf Lock.

The Charenton Floodgate provides an intermittent navigation connection through the West Atchafalaya Basin Protection Levee except at high stages in the Atchafalaya Basin requiring the closing of the floodgates. Floodgates in the guide levee on either side of Wax Lake Outlet for the Bayou Teche crossing at Calumet, La., will provide a navigable connection for through traffic on the existing Federal project on Bayou Teche, La. Similarly, Berwick Lock in the West Protection Levee at Berwick, La., provides a navigable connection for the existing waterway.

Plans and elevations of bridges crossing Old River and Atchafalaya River and Outlets are shown on Plates B80 and B81.

No improvements have been made on the Atchafalaya River nor in the Atchafalaya Basin by local interests specifically in the interest of navigation. Oil companies have dredged numerous minor access channels to oil well sites and have constructed a number of oil loading docks.

Transportation and utilities

Improvement of the channel of the Atchafalaya River and construction of the West Atchafalaya and Morganza Floodways have necessitated relocation or alteration of three important highways and three railroad lines in addition to numerous power and pipeline crossings.

Crossing the Atchafalaya River proper, the combination highway and railway bridge carrying Louisiana State Highway 30 and the Kansas City Southern Railroad at Simmesport, and the Missouri Pacific Railroad bridge at Krotz Springs have been lengthened and new deeper piers provided where necessary. Similar modification of the Texas and Pacific Railroad at Melville is presently under construction.

Spanning the Morganza Floodway, high-level crossings of the Texas and Pacific Railroad and Louisiana State Highway 30 at Morganza are under construction as a part of the Morganza Control Structure; while the high-level crossing of the Texas and Pacific Railroad from McKneely to Red Cross and high-level crossings of the Missouri Pacific Railroad and U. S. Highways 71 and 190 from Lottie to Krotz Springs have been completed.

The above described major utilities plus additional bridge, power and pipeline crossings are shown on Plates B79 through B81, "Utility Crossings."

Modifications of Old and Atchafalaya River bridges have been made as a result of channel changes. Table 31 and Plate B85 show comparative areas and sections for the Old River abandoned bridge at Torras, La., during the period 1903 to 1951. Table 30 and Plate B82 illustrate the changes of areas and sections of the Atchafalaya River bridge at Simmesport, La., during the period 1880 to 1951.

Factors Pertinent to the Problem

Stream flow

Composition. The Atchafalaya River discharges virtually the entire flow of Red River which ranges from 100,000 to 300,000 c.f.s. during the spring floods, and drops to a few thousand c.f.s. during the low-water season. About 22 percent of Mississippi River water is diverted to the Atchafalaya River via Old River during flood season, contributing 100,000 to 500,000 c.f.s. under present conditions. Low-water flow diverted through Old River ranges up to 100,000 c.f.s. The annual composition of Atchafalaya River water at Simmesport, La., in terms of inflow from Old River, Red River, Ouachita River, and local inflow from 1928 to 1949 is shown on Plate B86 and Table 32. The composition is extremely variable and depends on the relative magnitudes of the floods on the Red River and on the Mississippi River.

The amount of flow diverted through Old River is a function of the relative discharge capacities of the Lower Mississippi and Atchafalaya Rivers. The annual percentage of the total flow at the latitude of Old River carried by the Atchafalaya River during the period 1900 to 1950 is listed in Table 33, "Flow at Latitude of Old River." The flow of the Atchafalaya River at Simmesport has increased from 10 percent of the total at that latitude in 1900 to 30 percent in 1950. The increase in Simmesport discharge is clearly illustrated on Plate B87 where annual flow is compared with the 1900 to 1950 average annual flow. From 1900 to 1941 the flow averaged 11 percent less than the average for the period. From 1942 to 1950 an increase above the average is apparent, reaching a maximum increase in 1950 of 132 percent above the period average. Red River Landing flow during the same period fluctuated about 30 percent either way but showed no pronounced trend. The annual variations of flow at Red River Landing and Simmesport for the period 1900 to 1950 are presented in Table 34 and Plate B87, "Percent of Annual Flow with Reference to Average Annual Flow for Period." The diversion of flow from Mississippi River through Old River, shown in Table 35, "Percentage of Annual Mississippi River Flow through Old River," has increased from about 11 percent in 1881 to 22 percent in 1950. At the present time flow in Old River is infrequently reversed to direct Red River discharge into the Mississippi River. Occurrences of this phenomenon are listed in Table 36, "Direction of Flow of Old River at Barbre Landing, La."

Stage and discharge cycle. Since about 1900 a gradual but steady enlargement of Atchafalaya River discharge capacity is evident, accompanied by an increasing diversion of flow down the Atchafalaya River channel. Records of discharge in Atchafalaya River at or near Simmesport, La., are available since 1880. The annual discharge capacity for stages of 10, 25, 40 and 45 feet are plotted on Plate B88, "Rate of Increase of Discharge Capacity of Atchafalaya River." Prior to about 1900, observations were considerably affected by crevasses and to a less degree by method of observation. Unusual discharge in 1882, 1884, 1890 and 1892 is attributed to crevasses. Subsequent to 1900, excursions of discharge from a mean trend became smaller and less frequent. Trends of discharge for 10, 25, 40 and 45 feet on the Simmesport gage are extrapolated from experienced observations to 1960.

Relationship between the discharge in the Atchafalaya River at Simmesport, the Mississippi River at Red River Landing and Tarbert Landing and the Red River at Acme in these four years, 1927, 1937, 1945 and 1950, is shown in Table 26, "Elements of Discharge at Simmesport and Red River Landing." It is noted from this table that 23 percent of the Mississippi River flow at Tarbert Landing was carried off by the Atchafalaya River via Old River at the peak stage in 1937, with 18 percent in 1945 and 24 percent in 1950; and that during the 1945 flood, the Atchafalaya River carried 661,000 c.f.s., slightly in excess of the required flood-carrying capacity for the project or design flood referred to on page B5.

The rapid enlargement of the Atchafalaya River is evidenced by peak discharge for the years 1927 and 1945. With a stage of 53.3 feet at Simmesport on 14 May 1927, the discharge was 460,000 c.f.s. With a stage of 51.4 feet at the same location on 28 April 1945, almost two feet *lower* than in 1927, the discharge was 661,000 c.f.s., or 201,000 c.f.s. larger.

In the reach immediately below Old River, the Mississippi River bankfull areas have decreased an average 10 percent during the over-all period 1882 to 1950. These data are shown in detail in Table 37, "Areas Below Bankfull Stage, Mississippi River, Mile 301.7 to 288.0." Data for selected ranges are presented on Plate B89, "Annual Variation of Bankfull Areas of Selected Reaches of Mississippi River and Average Percent Diversion of Flow through Old River, 1882-1950."

The stage-discharge relation at Red River Landing and Simmesport for the period 1880 to 1950 has been analyzed for indications of progressive change. Such change is evident at Simmesport where a progressive shift of the relation toward greater discharge is apparent. The relation at Red River Landing undergoes a lesser and generally random change and is considered comparatively stable. The stage-discharge relation for all important stations of interest on the Mississippi, Red and Atchafalaya Rivers is shown on Plates B41 through B50.

Cross sections of the Red River Landing discharge range for available years from 1882 to 1950 are plotted on Plate B90, "Comparative Sections of the Mississippi River at Red River Landing Discharge Range."

The trend of average monthly and annual stages of the Mississippi River at Red River Landing, La., for periods 1872 to 1950 is shown in Table 38.

Slope. An analysis of the stage-discharge relation of the Mississippi River at Tarbert's Landing and Red River Landing, which bracket Old River, reveals a close similarity in stage variations. Between 1933 and 1950 the stage at Tarbert's Landing for one million cubic feet per second shows a decrease of five feet, with a four-foot decrease at Red River Landing over the same period for a somewhat smaller discharge. Slope is not appreciably affected by these changes.

The water surface slope in Red River below Alexandria is extremely variable, being dependent on Mississippi River backwater conditions. No discernible trend is indicated.

A study of high-water stages at the latitude of Old River revealed that water surface slopes through Old River have reversed during the past seventy years. Prior to about 1927, stages at Barbre Landing were generally higher than at Red River Landing indicating a preponderance of flow from Red River to the Mississippi. In more recent times the trend has been toward a preponderance of flow from the Mississippi River to the Atchafalaya. Very rarely now does flow enter the Mississippi from the Red. Whereas in the earlier period the Atchafalaya was incapable of handling the flow of Red River, it has now enlarged to better than twice the capacity of the Red and derives a major portion of its flow by diversion from the Mississippi.

Slopes in the Atchafalaya River are progressively flatter within the leveed reaches, and comparatively steeper through the Atchafalaya Basin. For a discharge of 350,000 c.f.s. at Simmesport in 1929 the water surface was 49 feet m.s.l., and at Atchafalaya, 54 miles downstream, 22.5 feet m.s.l., a differential of 26.5 feet. In 1950 for a discharge of 350,000 c.f.s. at Simmesport, the water surface elevation was 39.5 feet m.s.l., a lowering of 9.5 feet in 21 years, and 26 feet m.s.l. at Atchafalaya, an increase of 3.5 feet in the same period. The 1950 slope differential was 13.5 feet. These changes are presented graphically on Plate B91, "Atchafalaya River Water Surface Profiles for 350,000 c.f.s.," and reflect the adjustment of the river to its confinement by levees.

Below the levees steeper slopes have resulted from silting of the lower basin. That the Atchafalaya is engaged in pushing an efficient channel to the Gulf is plainly indicated by comparative surveys plotted on plan and profile Plates B21 through B27. The process involves first the deposition of a sedimentary floodplain and then cutting a channel across it. The trend to steeper slopes is reversed as the efficiency of the new channel increases and will eventually result in lesser slope being required. Studies of surveys since 1916 indicate that such a channel is being developed at a rate of about one-half mile per year. Continuation of this rate would provide an efficient channel to the Gulf of Mexico by about 1985 or 1990.

Discharge elements. Discharges of the Mississippi and Atchafalaya Rivers at Red River Landing and at Simmesport, respectively, have been analyzed as to velocity and area elements for the great floods of 1927, 1937, 1945 and 1950. The Simmesport range of the Atchafalaya River shows a chronological increase in both velocity and cross-sectional area, while at Red River Landing the Mississippi River shows an increase in velocity and decrease in area. All changes are of the order of 10 to 20 percent. Stages are generally lower for consecutive floods at both ranges. Supporting data are presented in Table 26, "Elements of Discharge at Simmesport and Red River Landing."

Distribution of flow in Atchafalaya Basin:

Procedure. Flood flow in the Atchafalaya Basin is carried partly within the major distributary channels and partly as overbank flow confined between the East and West Atchafalaya Basin Protection Levees. Distributions of 1937, 1945 and 1950 flood flows in the basin are diagrammed on Plates B51 through B53. Observations of flow in main and secondary channels were made near the crest to provide the basic data for these charts. However, as measurements were not taken at the time of peak discharge, such values were adjusted to represent crest conditions. This adjustment was generally in ratio to the discharge change at Simmesport, La.

The flow elements thus established were further adjusted for consistency of flow at reach boundaries, supplemented by calculations with Manning's formula.

Water surface contours, shown at one-foot intervals, are based on a number of gage readings and high-water marks. Profiles were plotted along the guide levees and main channel to facilitate interpolation of contour intervals. Adjustments were made as required by considerations of continuity.

At some points abnormal topographic conditions had considerable effect on flow distribution and water surface elevations. The south bank of Little Atchafalaya River is the most outstanding example of this condition. This bank is generally above river stages, thereby restricting southward flow to distributary channels that cut through the ridge.

Discussion. Development of the trend of distribution of flow in the Atchafalaya Basin, based on flood flows of 1937, 1945 and 1950, presents a complex problem when it is considered that the discharge of 1937 varied greatly from those of 1945 and 1950 and that many man-made changes took place during that period. Since the 1937 flood was considered smaller than those of the other two flood years, about 170,000 c.f.s. less, direct comparison is considered impractical. In the 1937 flood much of the overbank flow was of such shallow depths that flow patterns were much less regular than those experienced in 1945 and 1950.

The extension of the levee to Butte la Rose, completed prior to the 1949 high-water season, resulted in a stage increase of the Atchafalaya River at the end of the East Atchafalaya River levee of over two feet. This stage increase decreased to a negligible amount at the lower end of the Whiskey Bay Pilot Channel Extension reach of the Atchafalaya Basin main channel. The main channel from this point to Mile 90 shows no pronounced change in carrying capacity for the period 1945 to 1950. From Mile 90 to Mile 98, the reach of recent alluvial deposits, the 1950 flow line indicated considerable deterioration of the cross-sectional area. The backwater effect of this deterioration extends upstream to about Mile 84. Below Mile 98 channel deterioration is evidenced by excessive deposits.

Along the West Atchafalaya Basin Protection Levee, except for the obvious effect of the West Atchafalaya River Levee Extension to Butte la Rose, there is no appreciable change in overbank and secondary channel carrying capacities during the period 1945 to 1950. A stage increase of about 0.9 foot is indicated for the Grand Bayou loop south of Round Lake. Stage increases below this point are caused by the deterioration of the main flow carrying channels.

Along the East Atchafalaya Basin Protection Levee considerable changes in flow conditions have taken place since and probably during the high water of 1945.

During the 1945 high water the dike across the mouth of Alabama Bayou and adjacent to the head of the Whiskey Bay Pilot Channel was flanked and subsequently destroyed. Other gaps in the spoil bank of the pilot channel also developed. The enlargement of these gaps, combined with the increased stages resulting from the extension of the West Atchafalaya River levee greatly increased the flows of highly sedimentary waters into the upper reaches of the eastern portion of the basin. This phenomena resulted in the formation of large deposits halfway across the basin from the head of Whiskey Bay Pilot Channel to and including the cross-basin ridge formed by upper Grand River.

At the time of the 1937 high water the eastern section of the basin was honeycombed by a network of interconnecting bayous and sloughs whose combined capacity carried the major amount of the overbank flow assigned that sector. These waterways are now entirely disconnected in the eastern portion of the basin and are nonexistent in the western part.

The progressively increasing outflow of the enlarged Atchafalaya River into the upper reaches of the eastern section of the Atchafalaya Basin combined with an attendant decreasing flow capacity of that area as a result of sedimentation has resulted in a trend of increased basin stages for a given flood magnitude, the ultimate stage being contingent on man-made restrictions or improvements of the Atchafalaya River and Basin.

Hydrographic comparisons

Comparative cross-section elements were computed and tabulated for each year of record subsequent to 1880 on the Red River from Mile 6.8 to Mile 35.3, on the Mississippi River from Mile 318.6 A.H.P. to Mile 277.1 A.H.P., on the Old and Atchafalaya Rivers from the Mississippi River to Mile 54.3 of the Atchafalaya River, on the Atchafalaya Basin main channel from Mile 54.3 to Mile 75.0, and on the Atchafalaya River and Outlet below Mile 54.3. These elements are based on bankfull and mean low water datums shown on Plates B92 and B93. For study purposes, the various streams were divided into reaches of approximately 5 miles each and composite reach elements developed. The average number of surveyed ranges used in preparation of the reach data are shown in Table 39. Detailed coverage of pertinent waterways is discussed below.

Red River. The part of Red River considered in this study extends from Mile 6.8, its junction with Old River, to Mile 35.3, a distance of about 28.5 miles. For purposes of this study, the river has been divided into reaches each about 5 miles in length, with reach 1R located at the lower end of the stream and reaches 2R, 3R, et seq., lying progressively upstream, as shown on Plate B54. Comparative cross-section elements have been computed and tabulated for each year of record and are shown in Table 40, "Comparison of Cross Section Elements by Reaches for Period 1882-1950." Graphic display of cross-section elements is shown on Plate 94, "Cross Section Elements by Reaches in Relation to Time and Comparison of Cross Section Elements by Reaches."

Comparison. Throughout the period of record from 1892 to 1950, the cross-section elements of Red River have undergone no drastic changes, although variations are noted for the intervals between surveys. From 1892 to 1910, the bankfull and mean low water dimensions of the stream along reaches 1R through 5R generally decreased with the maximum rate occurring in reach 1R, as will be noted from an inspection of Plate B94, while the dimensions of reach 6R showed a slight increase as reflected by the gain in mean low water area of 600 square feet and at bankfull by an area of about 1,000 square feet.

Between 1910 and 1938, at mean low water, the areas of all reaches increased by 1,000 to 4,000 square feet. At bankfull stage, the areas increased by 2,000 to 6,000 square feet. Area gain was the result generally of increased depth at reaches 1R through 3R and by increases in depth and width at reaches 4R through 6R.

Between 1938 and 1950, at mean low water, the areas of all reaches, excepting reach 4R decreased by 600 to 3,000 square feet, the area of reach 4R increasing by 6,000 square feet. At bankfull stage, the areas of reaches 1R and 2R decreased by 2,380 and 10 square feet, respectively, while areas of reaches 3R through 6R increased from 340 to 11,000 square feet. Changes in area at mean low water resulted from depth changes since at all reaches the widths generally increased. At bankfull stages, the change in area at reaches 1R and 2R was caused by decreased depths, the widths generally increasing, and at reaches 3R and 4R the increase in area was the result of greater depths and widths, while at reaches 5R and 6R the change was the result of greater widths as depths declined slightly.

Summary. Over the 58-year period of record, as evidenced by the results of four surveys, small change has been noted in the channel characteristics of Red River. Generally, the trend has been a decrease in capacity at bankfull and mean low water caused by lesser depths though widths generally have increased slightly. It must be remembered that the period of record as defined herein is antedated by the significant man-made works in the area, i.e., removal of Red River rafts in 1828; Shreve's Cutoff in 1831; removal of the Atchafalaya River raft in 1840; and construction of the two sill dams in the Atchafalaya River in 1888 and the sill dam in Red River in 1891.

The minor changes noted in Red River at this latitude are not significant and are mentioned in connection with the enlargement of the Atchafalaya River at this time to show the lack of effect on the latter stream's behavior and possibly a slight negative value in the over-all picture.

Mississippi River. The part of the Mississippi River considered to be pertinent to the problem and included in this study extends from Mile 277.1 to Mile 318.6 above Head of Passes, a distance of about 42 miles. This length has been divided into eight reaches averaging about 5 miles each, beginning with reach 1M at Mile 318.6 and increasing in numbers downstream to reach 8M which ends at Mile 277.1 A.H.P., as shown on Plate B54. Old River connects with the Mississippi River at Mile 301.5 A.H.P. at the upstream end of reach 4M.

The reach average areas, widths, and depths for below bankfull and mean low water stages, as obtained by computing the arithmetic average of the elements of each surveyed range falling within the limits of each reach for period 1882 to 1950, are shown in Table 41, "Comparison of Cross-Section Areas," Table 42, "Comparison of Stream Widths," and Table 43, "Comparison of Average Depths." Graphic displays of the tabulations are shown on Plate B95, "Comparison of Cross-Section Elements," and on Plate B96, "Cross-Section Elements by Reaches in Relation to Time."

Comparison. A study of the reach areas of the Mississippi River over the period 1882 to 1950 shows that for the same reach, great variations in area have taken place within short periods. Generally, the maximum change in dimensions cannot be applied at any one reach for any particular year since variations occurred throughout the period of study, 1882 to 1950. Maximum increases in area were noted at reach 2M for the period 1895 to 1922. Radical decrease in area has also been noted at reaches 7M and 8M for the same periods. Generally, for the upper reaches depth increases have been offset by decreases in width, whereas along the lower reaches depths have declined generally. The over-all result has been that the upper reaches remain at about their original capacities whereas the lower reaches have decreased in areas.

Summary. A detailed analysis of the fluctuations of the dimensions of Mississippi River reaches in the light of sustained high and low discharge is not possible in view of the infrequent surveys along this part of the river. However, the over-all result of high and low discharge, man-made improvements, and progressive Old River diversion on the Mississippi River reaches is quite apparent, and from these data certain definite conclusions concerning reach behavior can be obtained. In 1882, almost half a century after Shreve's Cutoff, when the enlargement of the Atchafalaya River had progressed to the point where remedial measures were being undertaken, wide disparity in bankfull areas of the reaches under study were noted. The upstream reaches, 1M through 4M, varied in area by over 20,000 square feet, while reaches 5M through 8M varied by about 14,000 square feet. The four upstream reaches had an average bankfull area of about 220,000 square feet, while the reaches downstream from the Old River junction averaged 200,000 square feet. Down through the years these averages as well as individual dimensions fluctuated down or up depending on whether a sustained low flow or a period of flood discharge was experienced.

The 1950 survey shows that reaches 1M through 4M have attained an average bankfull area of 215,000 sq. ft., an average decrease of 5,000 sq. ft. and that the greatest difference in area between any two of these four upper reaches is about 6,000 sq. ft. compared with 20,000 sq. ft. difference existing in 1882. The survey further shows that reaches 5M through 8M average 172,000 sq. ft. in area at bankfull stage, an average decrease of 28,000 sq. ft., with a maximum difference of 6,000 sq. ft. between any two of the four reaches in 1950 as compared to the difference of 14,000 sq. ft. noted in 1882.

It will be noted that over the period of years, 1882 to 1950, the four upstream reaches underwent only minor changes in dimensions, whereas the areas of the four downstream reaches were reduced principally because of reduced depths, although widths at reaches 7M and 8M also decreased.

Old River. Location of the Old River reach, comprising the entire length of Old River, is shown on Plate B54. Tabulated comparative cross-section elements of the Old River reach and graphic illustrations of the tabulated data for the period 1894 to 1951 are shown in Table 44 and Plate B97, respectively.

Comparison. From 1894 through 1922 bankfull areas increased from 28,000 square feet in 1894 to 36,000 in 1922, an enlargement of 8,000 square feet, as a result of progressively increasing depths attended by fairly stable widths. During this period mean low water areas of about 9,000 square feet apparently remained fairly constant.

Subsequent to 1922, probably as a result of the 1927 flood, bankfull areas increased from 36,000 square feet in 1922 to 61,000 in 1950, an increase of about 70 percent. Mean low water areas increased from about 9,000 square feet in 1922 to about 21,000 square feet in 1950, an increase of about 130 percent. These increases in areas resulted from increased widths and depths.

Summary. Plate B97 indicates the extent and rate that channel enlargement in Old River has followed the extension of the Atchafalaya River levees shown in Table 29. From 1894 to 1950 bankfull reach areas of Old River increased from 28,000 square feet in 1894 to 61,000 square feet in 1950, an increase of about 120 percent. Mean low water reach areas increased from 8,000 square feet in 1910 to about 21,000 square feet in 1950, an increase of about 160 percent.

Atchafalaya River and Outlets. The Atchafalaya River from its head to Mile 54.3 is divided into 11 reaches, each approximately 5 miles long, with reach 0 at the head and reach 11 terminating at Mile 54.3. Locations of these reaches are shown on Plate B54. Tabulated comparative areas, widths, and depths of this portion of the Atchafalaya River by reaches for the period 1880 to 1950 are shown in Tables 45, 46 and 47, respectively. Graphic illustrations of the tabulated data are shown on Plates B98 and B99. Increases in cross-sectional areas, below mean low water and bankfull stages by reaches, expressed in percent of 1880 areas, are listed in Tables 48 and 49, respectively. A tabular comparison of 1938 and 1950 bankfull cross-section reach elements, based on the 1950 datum, is shown in Table 50.

The Atchafalaya Basin main channel, extending from Mile 54.3 to Mile 75.0, is divided into 5-mile reaches identified as reaches 12 through 15. Locations of these reaches are shown on Plate B54. Tabulated comparative cross sections of these reaches are listed in Table 51.

The Atchafalaya River and Outlets from Mile 54.3 to Mile 78.8, junction with Mile 73.1 of the main channel, is divided into 5-mile reaches identified as reaches 12A through 16A. Locations of these reaches are shown on Plate B54. Tabulated comparative cross-section elements of these reaches are listed in Table 52.

Comparison. Prior to 1880 Darby, in his "Geographical Description of Louisiana" states:

> "The Atchafalaya was first obstructed by timber in 1778." In Ellicott's journal we find that ". . .this branch (the Chafalia), notwithstanding its magnitude, is not navigable to the Gulf of Mexico, owing to the immense floating bridge or raft across it, of many leagues in length, and so firm and compact in some places that horses and cattle are driven over it. This surprising bridge or raft is constantly augmenting by the trees and rubbish which the Chafalia draws out of the Mississippi."

Following the Louisiana Purchase, Major Stoddard who took possession of upper Louisiana in 1804, described the Atchafalaya as being completely obstructed by logs and other material a few miles from its head. He stated that in leaving the Mississippi River about three miles below Old River, the Atchafalaya was about 200 yards wide, and had a depth at low water of 18 feet and at high water of about 30 feet. Thirty miles below its head the river was obstructed by a raft of wood bound together by a heterogeneous mixture of ligneous and other matter. In the course of 20 miles the navigation was choked by 10 or 12 similar rafts and he calculated that they totaled not less than 9 miles in length. He observed that some of the rafts formed good bridges and were passable at all seasons. These rafts rose and fell with the water and were justly termed floating bridges.

In 1817 Darby wrote:

> "On the subsiding of the spring floods, I have seen the water flowing from the Atchafalaya into the Mississippi. This circumstance is very contrary to the common opinion on the subject but it is true. Indeed, so completely is the communication cut off at low-water between the two rivers, that very often a common canoe cannot be taken from one to the other."

Prior to 1831, Red River discharged into a bend of the Mississippi River from which the Atchafalaya was supplied. Navigation of the Lower Red River was impaired by backwater from the Mississippi River which occasionally extended to Alexandria, La., on the Red, and to Monroe, La., on the Ouachita River. The Atchafalaya was rafted heavily. After Shreve's Cutoff in 1831, Red River sought the Mississippi River by the shortest route, through Upper Old River, north of Turnbull's Island; while Lower Old River, from the head of the Atchafalaya to the Mississippi River, silted up and bore a heavy willow growth.

To maintain a navigation route to Opelousas, La., and the Atchafalaya country the State of Louisiana in 1840 initiated the work of removing the raft at the head of the Atchafalaya River. To this work and the disturbance of the equilibrium between the Mississippi, Red and Atchafalaya Rivers by Shreve's Cutoff was due the initial enlargement of the latter stream.

Immediately upon the removal of the obstruction from the upper part of the Atchafalaya its rapid enlargement commenced. Portions of the raft that had been left, as not endangering navigation, were washed out piecemeal, the bed was deepened, and heavy caving was started in the bends and on both sides of narrow reaches. Lands previously exempt from overflow were annually submerged by the increasing volume from above and by the nonextension of proportional relief through the lower reaches of the stream. The recorded increase in cross-sectional area at the head of the Atchafalaya River between 1851 and 1870 was from 24,400 to 52,100 square feet. The increase of discharge, estimated by the Board of Engineers reporting on Major Benyaurd's report, between 1878 and 1879 was from 120,000 to 180,000 cubic feet per second.

Besides the increase of discharge, levees were built and outlets closed. By 1874, 37 outlet bayous were closed causing the Atchafalaya to scour its bed, deepening and widening it everywhere. The process was gradual and the levees in existence in 1874 constituted the third levee system that had been constructed, others having succumbed to caving banks.

For several years following Shreve's Cutoff, the flow of Red River passed to the north of Turnbull's Island en route to the Mississippi River. In 1873, after great enlargement of the Atchafalaya, Lower Old River, which had silted and grown up with willows, cut out and the northern channel closed up. Red River discharge followed the line of least resistance down the Atchafalaya and only surplus Red River discharge passed along the southern channel to the Mississippi River.

As the Atchafalaya continued to enlarge, its demands became more exacting, and this surplus was so reduced and uncertain that Lower Old River became a wide, shallow slack-water basin receiving sediment alternately from the Mississippi and Red Rivers. In 1876 the process had nearly closed the low-water connection. Near the lower end of Turnbull's Island the waterway was only about 100 feet wide and 20 inches deep. By the end of the low-water season the bar cut out. In 1877 a similar bar formed nearly a mile toward the Atchafalaya, the scoured channel of 1876 remaining open. The new bar was dredged out by the State of Louisiana. Similar obstructions occurred in 1878, 1879 and 1880 reforming each year at points nearer the Atchafalaya, with channels dredged in previous years remaining open.

In portions of the Atchafalaya River the enlargement due to erosion had become so alarming during the latter part of the nineteenth century, in consequence of the possibility of the diversion of the Mississippi River through this shorter route to the Gulf of Mexico, that in order to forestall such a catastrophe two mattress sills were laid out across the Atchafalaya in 1888 at a point about four miles below its head. These sills extended across the stream to the tops of the higher water banks, and as anticipated, they practically fixed the section in their immediate vicinity and prevented abnormal increases in discharge.

Meanwhile changes were going on in Old River and to a much greater extent in the Atchafalaya about 20 miles from its head. Erosion was unusual in form and intensity. Caving banks were often confined to points rather than bends, and instead of the deepest water existing in reaches of contracted channel, excessive depth was coincident with extreme width.

In 1880 with the levee system constructed along both banks of the Atchafalaya River through reach 2, and along the right bank through reach 5, the bankfull area of the river at reach 2 and upstream therefrom averaged about 55,000 square feet. Below reach 2 the partially leveed and unleveed reaches decreased sharply in area down to 20,000 square feet at reach 8. The stream thus presented a unique appearance in that its channel near its source was 2.75 times as large as its channel near its lower extremity.

During the 24-year interval prior to 1904, levee construction along the Atchafalaya River was extended to include reach 7 on both banks and to include reach 8 on the left bank. Ten major floods were experienced during this time among which was the flood of 1882, which is probably the most extensive in the history of the Mississippi Valley. The levees did not offer complete immunity from floods as they were overtopped and breached many times during the 24-year interval. The 1904 survey revealed that during the 24-year period the bankfull areas of newly leveed reaches increased by amounts in the category of 15,000 to 20,000 square feet, while the areas of leveed reaches at the beginning of the period showed no important change, the enlargement resulting from a combination of increased width and depth.

In 1904 the bankfull areas of reaches 0 through 6 averaged about 55,000 square feet, while the areas of reaches 7, 8 and 9 decreased sharply from this magnitude to an area of about 20,000 square feet at reach 9 with reaches 10 and 11 having bankfull areas of 19,000 and 17,000 square feet, respectively. The Atchafalaya River thus presented a more modified appearance in that along the upper half of its length reaches were comparable in area, whereas along the unleveed or partially leveed lower half of the stream the reaches were still comparably deficient in size.

During the 12-year interval from 1904 to 1916, four major floods were recorded. Also during this period, levee construction was extended along both banks of the river to include reach 8. The 1916 survey showed that during the 12-year interval consistent enlargement of the Atchafalaya had taken place along reaches 0 through 8 in the category of about 6,000 square feet. The unleveed reaches 9, 10 and 11 meanwhile had enlarged by 20,000 square feet in area. These enlargements resulted principally from increased depth, although widths had increased proportionately along the lower extremities of the river.

The 1916 survey showed that the areas of reaches 0 through 6 averaged slightly in excess of 60,000 sq. ft. at bankfull stage. The areas of reaches 8, 9 and 10 averaged about 40,000 sq. ft. at bankfull with the area of reach 11 averaging about 30,000 sq. ft.

During the 15-year interval just prior to 1931, four major floods were experienced, among these being the 1927 flood, admittedly the worst of record, and which resulted in numerous levee breaks. During this period levees were extended along the left bank to include reach 11 with no further extension along the right bank. The 1931 survey showed generally a moderate increase in bankfull areas of reaches 0 through 7 during the 15-year interval, averaging from about 2,000 to 5,000 sq. ft., excepting reach 4 which increased by 14,000 sq. ft., the latter probably being caused by the Melville crevasse in 1927. Reaches 8 through 11 showed marked increases of between 13,000 and 19,000 sq. ft., as a result of abnormal width increases.

The 1931 survey showed that the bankfull areas of reaches 0 through 3 averaged about 64,000 sq. ft., areas of reaches 4 and 5 were in excess of 70,000 sq. ft., and areas of reaches 6 through 11 averaged about 55,000 sq. ft. Essentially no levee extension was made during the year.

From 1931 to 1932 survey data indicated enlargement at bankfull stage of reaches 0 through 3 in amounts varying from 5,000 to 15,000 sq. ft., attributable to increased depths. Reaches 4, 5, et seq., enlarged by 200 to 2,000 sq. ft., excepting reach 6 which decreased by 200 sq. ft.

The 1932 survey showed that the bankfull areas of reaches 0 through 5 averaged about 73,000 sq. ft., the areas of reaches 6 through 10 about 57,000 sq. ft., and reach 11 about 50,000 sq. ft. During the year levee construction was extended along the right bank to include reach 10. Only medium high water was experienced during this time. From 1932 to 1933 survey data indicated rather consistent enlargement along the entire length of the stream, averaging about 2,000 to 3,000 sq. ft. as a result of depth increases and some minor changes in width.

The 1933 survey showed that the areas of reaches 0 through 5 averaged about 75,000 sq. ft. at bankfull stage, and the areas of reaches 6 through 10 followed a pattern of about 60,000 sq. ft. average, whereas reach 11 had an area of 51,000 sq. ft. For about eight months of the period 1933 to 1934 extreme low water was sustained. The result of this low water was felt along the entire length of the stream as the 1934 survey showed that all reaches had decreased in area at bankfull stage by amounts ranging from 800 sq. ft. to 9,000 sq. ft. Depths decreased along the entire length of the stream, widths remaining practically constant.

The 1934 survey showed that the areas of reaches 0 through 5 averaged about 68,000 sq. ft., the areas of reaches 6 through 10 about 57,000 sq. ft., and reach 11 about 48,000 sq. ft. at bankfull stage.

The 1935 survey was made following the moderate high water of that year and indicated increase in areas of all reaches excepting reach 6 which showed no change and reach 7 which decreased by 100 sq. ft. The maximum enlargements noted for this one-year period, along reaches 0 through 4, were between 3,000 and 8,000 sq. ft. Depths generally increased all along the length of stream.

The 1935 survey showed that the areas of reaches 0 through 5 at bankfull stage averaged about 73,000 sq. ft., reaches 6 through 10 about 58,000 sq. ft., and reach 11, 51,000 sq. ft. During the two-year interval to 1937, levee construction was extended along the right bank through reach 11. Also during the interval the flood of 1937 occurred, which had a sustained high flow for two months. The 1937 survey indicated two-year increases in bankfull areas of reaches 0 and 1, and 5 through 11, whereas reaches 2, 3 and 4 decreased in area. No appreciable over-all change in widths was noted, the area change being the result of depth changes. The 1937 survey showed that the areas of reach 0 were 83,000 sq. ft., reaches 1 through 5 averaged about 73,000 sq. ft., reaches 6 through 10, 64,000 sq. ft., and reach 11, 60,000 sq. ft.

The 1938 survey showed the areas of reach 0 to be 84,000 sq. ft.; reaches 1 through 5 averaged about 74,000 sq. ft.; and reaches 6 through 11 to average between 62,000 and 70,000 sq. ft. at bankfull stage. At the end of the 6-year interval prior to 1944 increases in areas of reaches 0 through 4 by 1,200 to 4,000 sq. ft., and of reaches 6, 8 and 9 by 800 to 3,000 sq. ft. were noted. The areas of reaches 5, 7, 10 and 11 decreased by 200 to 3,000 sq. ft. resulting from decreased depths. The 1944 survey showed the area of reach 0 to be 88,000 sq. ft., the area of reaches 1 through 5 to average about 76,000 sq. ft., and the areas of reaches 6 through 11 from 60,000 to 67,000 sq. ft.

From 1944 to 1945 all areas had increased by varying amounts with maximum increases of 10,000 and 12,000 sq. ft. at reaches 2 and 11, the smallest increment being 50 sq. ft. at reach 0.

In 1945 the bankfull area of reach 0 was measured at 88,640 sq. ft., areas of reaches 1 through 5 averaged 84,000 sq. ft., and areas of reaches 6 through 11 between 68,000 and 77,000 sq. ft. Flood stages were experienced each year during the period 1945 to 1950 and no crevasses were experienced.

~~At the end of the five-year period, the survey of 1950 showed the area~~ of reach 0 to be 99,090 sq. ft., an increase of 10,450 sq. ft., widths and depths having increased proportionately, the area of reaches 1 through 5 averaged about 93,000 sq. ft., an average gain of 9,000 sq. ft., and the areas of reaches 6 through 11 averaged about 80,000 sq. ft., a gain of about 8,000 sq. ft. resulting from depth increases.

The reaches downstream from Mile 54.3 Atchafalaya River are influenced by somewhat different conditions. For example, the Atchafalaya Basin main channel between Mile 54.3 and 75.0 and the Atchafalaya River and Outlet from Mile 54.3 to 78.8 are unleveed, consequently flood flows are not confined to the channels and pass practically unrestrained overbank through the wide, flat areas to the lower basin. The period of record for these reaches includes surveys made in 1916, 1938 and 1950 for purposes of comparison, with surveys in 1944 and 1945 for the main channel only. These data generally indicate that enlargement has taken place over the period of record, but at a rate considerably less severe than that which occurred in the leveed Atchafalaya River.

Summary. The continued enlargement of the Atchafalaya River is attributed to natural causes, such as changing flow conditions, and to man-made or artificial construction, such as channel excavations and levee construction.

Natural enlargement of Old and Atchafalaya River cross sections is a phenomenon that dates back to the earliest period of record, originating in general with Shreve's Cutoff and the removal of the Atchafalaya River rafts by the State of Louisiana in the period 1840 to 1861. This natural enlargement was continued and accelerated over the years as a result of the progressive extension of the levee system along both banks of the Atchafalaya River as development of the banks required such action. The average cross-sectional area of the upper eight reaches of the Atchafalaya River increased at bankfull stage from about 40,000 square feet in 1880 to 63,000 square feet in 1931, an increase of about 50 percent in 50 years. Since initiation of the improvement program in the Atchafalaya Basin the rate of enlargement has increased to attain an average bankfull stage of 89,000 square feet in 1950, an increase of an additional 50 percent approximately of the 1880 area. Such an increase occurred in 20 years or about two-and-one-half times the rate experienced prior to 1931.

The average cross-sectional area of the lower three reaches, 9 through 11, has increased at bankfull stage from about 18,000 square feet in 1904 to 54,000 square feet in 1931, an increase of about 200 percent in 27 years. Since 1931, the rate of enlargement has increased to attain an average bankfull stage of 83,000 square feet in 1950, an increase of an additional 50 percent approximately of the 1904 area. Such an increase occurred in 20 years or about one-fourth of the rate experienced prior to 1931.

Increase in the cross-sectional area of the river channel has been indicated by the increase in the flow of the Atchafalaya River. At a stage of 40.0 feet at Simmesport, La., the river had discharge capacities of 250,000, 310,000, and 440,000 c.f.s. in 1892, 1932, and 1950, respectively. The 60,000 c.f.s. increase in the earlier 40 years and the additional 130,000 in the latter 18 years reflects the more rapid average annual increase in river capacity since initiation of the improvement program of the Atchafalaya River and Basin.

The 1936 authorization of the improvement of the discharge capacity of the leveed channel of the Atchafalaya River without increasing stages and development of a central main channel through the Lower Atchafalaya Basin into Grand Lake, together with enlargement of openings through the existing railroad and highway bridges resulted in extensive dredging in the Atchafalaya River proper and through the Lower Atchafalaya Basin. Approximately 127,000,000 cubic yards of material were removed, about 22,000,000 from the river and approximately 105,000,000 from the lower basin under the improvement program. The majority of this work was done during the period 1933 to 1941.

Channel areas at the L. & A. Railroad bridge at Simmesport, La., and at the N.O.T. & M. Railroad bridge at Krotz Springs, La., were enlarged by dredging along the right descending bank under the authorized project. The Simmesport dredging, involving about 3,000,000 cubic yards, was completed in 1939. At Krotz Springs approximately 2,000,000 cubic yards were excavated in 1941 and an additional 2,700,000 cubic yards, to complete the work, were removed in 1946. Bridges at these places were modified, under the project authorization, by lengthening on the west side and construction of several deep piers prior to the initial dredging.

The T. & P. Railroad bridge at Melville, La., had not been modified under the project nor has channel improvement work been done to enlarge the opening through the bridge. However, the channel area at and in the immediate vicinity of the bridge has enlarged under the natural river action and interrelated artificial enlargement elsewhere along the river and through the basin. In this manner, the cross-sectional area at Melville has increased at a greatly accelerated rate since about 1935.

Prior to about the 1945 flood, the river channel in the immediate vicinity of the Melville bridge appeared to be reasonably stable. The progressive natural enlargement over the years had affected widening, principally along the east bank, but there has been no marked tendency toward appreciable deepening. Subsequent to the 1945 flood, a deep scour had developed along the left descending bank centered about 500 feet below the bridge. The 1950 hydrographic survey shows conditions in July and August with depths of 100 feet below mean low water. This condition, and the probability of migration of this hole upstream through the bridge, constitute a serious hazard to the structure. As an emergency measure, the railroad company placed riprap in the scour hole below the bridge and along the bank.

For the past eighteen years the natural enlargement of the Upper Atchafalaya River has been accomplished by a slow but steady deterioration in the flood-carrying capacity of the middle reach of the Atchafalaya Basin Floodway, caused chiefly by silt deposits therein. This has resulted in an increase in flood heights along the East Atchafalaya Basin Protection Levee for like discharges from a point a few miles above Upper Grand River to Morgan City. To avoid the build-up of dangerous flood heights along this levee, existing long-term planning for further development of the Atchafalaya

Basin main channel contemplates extensive dredging, as soon as funds are available, in the main channel from the head of Whiskey Bay Pilot Channel to a point several miles below Upper Grand River, with accompanying deposit of spoil along the east, or left, descending bank.

Channel alignment

Red River. The meander pattern of Red River over the period of record from 1808 to date is shown on the Plates B8, B9, and B10, "Red River, La., Plan, Profile and Sections," for the reaches under study. The bank lines prior to 1880 have been taken from land plats and show the high-water conditions, surveys of other years show mean low-water bank lines. It will be noted that the principal change to have been effected prior to 1880 is improved alignment of the stream. At Mile 20 (1950 survey), the bend in reach 3R ~~appears to be moving downstream, while the bend at~~ Mile 16 has been considerably straightened by reason of cutoff tactics. Bends at Miles 12.5 and 11.5 (1950 survey) have progressed downstream and now present curves with increased radii. At the lower end of reach 1R, below the site of the old sill dam location, and at the junction with the Old and Atchafalaya Rivers the channel has shifted progressively through the years to the west as a result primarily of dredging activities so that it now occupies a position about one-half mile from its 1880 position.

Mississippi River. Meanderings of the stretch of the Mississippi River considered under this study over the period of record from 1825 to date are shown on Plates B11 to B14, inclusive, "Mississippi River, La., Plan, Profiles and Sections." The 1825-1845 bank line shown on the maps was taken from land plats and shows high-water conditions, whereas subsequent surveys show the mean low water bank line. It will be remembered that reaches 1M, 2M, and 3M came into existence as a result of Shreve's Cutoff in 1831, previous to which time the Mississippi River flowed around the northern, western, and southern half of what is now known as Turnbull Island.

Since 1882 the upstream end of reach 1M has shown a marked tendency to move westward, due to the downstream migration of the bend in the river above this point. The bend at Mile 311 about the middle of reach 2M has also moved downstream with a maximum shifting of the channel 3500 feet to the east, towards the periphery of the curve during the period 1882 to 1950.

The full effect of the meander mentioned above is extended diminishingly downstream through reach 3M. At Mile 305 the channel shifted westward between 1895 and 1903, and has remained relatively stable since that time, whereas 2-1/2 miles downstream at the entrance of Old River, the Mississippi River channel has shifted progressively to the west as indicated by each survey of record, so that its present location is about 4000 feet from its position in 1882. The westward shift was accelerated following Carr Point Cutoff in 1944, a man-made cut into Old River across a peninsula-type bar extending between the two streams above their junction. This cutoff shortened the length of Old River by a distance in excess of one mile, and moved the bifurcation of the Mississippi River by that distance upstream.

Except for minor vagaries at the upper end of reach 5M, no apparent change has been noted in its relative position since 1882. The bend at Mile 290 in reach 6M has moved eastward since 1882 causing a general migration of the channel in that direction.

Reach 7M has remained comparably stable throughout the years since 1882, except for an apparent westward migration of the channel due to the river reducing its width by withdrawing from its east bank, with very little movement of its western bank line. The bend beginning at reach 8M has progressed downstream since 1882 causing an eastward shifting of the channel at Mile 280 of about 4000 feet.

Old River. Meandering of Old River over the period of record 1855 to date is shown on Plate B15, "Old River, La., Plan, Profile and Sections." Early surveys prior to Shreve's Cutoff in 1831 show the channel to occupy an area averaging from 3000 to 5000 feet wide, at which time it was the main channel of the Mississippi River. Following Shreve's Cutoff in 1831, the Mississippi abandoned this reach in favor of the shorter cutoff so that by 1880 the width of Old River had decreased to about 1000 feet, and has remained in this category with only minor variations along its central portions.

Considerable changes in alignment have occurred at Mile 0 (the junction with the Mississippi River) since 1880, due principally to the westward migration of the Mississippi River in this vicinity, and the dredging work done by the State of Louisiana in the channel of Old River, and by Carr Point Cutoff in 1944 by the United States. The over-all result has been that under 1950 conditions the Old River connection with ~~the Mississippi is approximately 6000 feet upstream (measured along the Mississippi~~ River thalweg) from its former location. This was made subsequent to and caused entirely by the Carr Point Cutoff.

Meanwhile along the middle portions of the stream, progressive widening of the bends at Miles 3 and 4.5 (1950 survey) have taken place, shifting the center line of the stream to the north in the former instance and to the south in the case of the latter, a maximum distance in both cases of about 900 feet since 1880.

At the western end of Old River, progressive changes have been taking place since 1880 with possibly the greatest change occurring since 1938. The westward bend in the Red-Atchafalaya alignment at the mouth of the former and head of the latter has straightened considerably by a progressive westward migration due principally to dredging activities since 1880, so that the junction of the three streams is now about 3000 feet west of the position it occupied in 1880.

Atchafalaya River. The meander pattern of the Atchafalaya River over the period of record from 1808 to date is shown on Plates B15 to B21, inclusive, "Atchafalaya River, La., Plan, Profiles and Sections," for that leveed portion of the river considered as the main stem, or from Mile 0 to Mile 54.3. The bank lines prior to 1880 have been taken from land plats and show high-water conditions; data subsequent to that date show mean low water conditions.

At the upper end of reach 0, the Atchafalaya River has undergone considerable changes since the first survey was made. Land plats dated 1808-1830 indicate a stream width of approximately 300 feet. Enlargement through the years, beginning with removal of the raft in 1840, has been progressive and migration of the channel at the upper end has been to the west as explained previously. At Mile 3.5, the bend in the river has progressed to the east so that the channel now occupies a location about 1300 feet from its original location. Elsewhere along the reach the stream has remained comparably stable except at the junction with reach 2, about Mile 8.0, as will be outlined below.

Great changes in alignment have taken place through the years along reaches 2, 3, and 4 with the resulting pattern much improved with respect to alignment. Migration has been to the west at Mile 8.0, straightening a bend in the channel at that point with a maximum shifting of the channel of about 2000 feet. Between Miles 9 and 10, a sharp reverse curve existing in 1880 has progressively moved downstream so that at present a comparatively straight channel exists at that point. At Mile 12.7 a sharp bend in the channel was eliminated by cutoff during the period between 1880 and 1904, with only minor meanderings at that point since. Slight improvement in alignment is being made at Mile 16 with the progressive downstream migration of the bend at this latitude. Bends at Miles 19 and 20 have also improved through the years as will be noted from the maps referred to.

Meandering along reaches 5 and 6 has generally been dormant excepting between Miles 24 and 26 where the downstream travel of two bends in the stream have improved the alignment at one place and made it worse at another.

Except for changes in widths and the slight downstream travel of a bend at Mile 34, no appreciable meandering has been noted along reaches 7 and 8.

Changes in the stream pattern along reaches 9, 10, and 11 have been generally due to vagaries in widths rather than exceptional meander patterns. Between Miles 43 and 46, however, improvement in alignment has been noted because of the downstream travel of two sharp bends. At the end of reach 11 about Mile 54, change without improvement in alignment has taken place progressively over the years with considerable movement of the channel since 1938.

Tides

Owing to the natural barrier formed by reefs across the mouth of Atchafalaya Bay, abnormally high stages frequently result from the discharge of Atchafalaya River floodwaters. Stages in excess of 3.0 feet m.s.l. developed from this cause have occurred twelve times since the gage was established in 1939. These stages were 4.7 feet m.s.l. in April 1945; 4.5 in March 1949; 3.6 in May 1944; 3.5 in June 1946; 3.4 in June 1945 and in March 1950; 3.2 in May 1941, in May 1947 and in June 1949; 3.1 in June 1947; and 3.0 in April 1944 and in May 1946.

During the period of record, stages above 3.0 feet m.s.l. have also been experienced on ten occasions owing to storms. These were 4.0 in December 1947; 3.8 in September 1948; 3.5 in October 1949; 3.4 in September 1947; 3.1 in August 1940 and in October 1945; and 3.0 in August 1942, in September 1942, in December 1949 and in August 1950. These stages were the result of storm tides during periods of relatively low discharge from the Atchafalaya Basin. A comparison of the stages which obtain these diverse conditions shows that higher tides occur more frequently as a result of the flood flows than of tropical storms.

Table 23, "Tidal Effects in Lower Atchafalaya Basin," is a tabulation of data obtained from a study of available records of gages located in the Lower Atchafalaya Basin. In column (4) are mean stages obtained by averaging hourly stages over a period of five years, 1944-1948, for all gages except Eugene Island, which is a mean for the entire period of record. In columns (5) to (10) are extreme stages and dates of occurrence. In columns (11) to (14) are mean tidal ranges and tidal lag times referred to tides at the Eugene Island gage. The mean ranges were obtained by a comparison of high and low stages during four flood seasons when flows at Simmesport approximated 300,000 c.f.s., and four slack seasons when flows approximated 100,000 c.f.s. In general, the range between high and low tides is 0.5 foot less during the high-water period than during the low-water period. The lag in time from extreme tides at Eugene Island to extreme tides at other gages is prolonged as the quantity of outflow increases. An examination of the charts from the recording gage at Krotz Springs discloses that only a trace of tidal effect was felt at this latitude during extreme low flows.

Floods

Protection of lands in the Atchafalaya Basin from flooding was begun about 1880 by constructing levees downstream from the head of the Atchafalaya River, with this work continued up to recent times. The initial effect of confinement was an increase in river stages, but gradually increased discharge capacity was developed by scouring action of the channel. This enlarged capacity resulted eventually in reduced duration of flooding.

Numerous crevasses occurred in the Atchafalaya River levees during the earlier floods, with this frequency of occurrence rapidly diminishing as the controlling levees were strengthened. Table 29 contains data on "Crevasses of the

Atchafalaya River." It is noted that the last of these breaks took place on 17 May 1927 at Melville. It was in this year that the most disastrous flood of record occurred, with flood levels attaining unprecedented heights and losses exceeding those ever before experienced in the Mississippi Valley. Legislation to provide protective works to prevent repetition of this disaster resulted in adoption of the Jadwin Plan or Flood Control Act of 15 May 1928, "An Act for the Control of Floods on the Mississippi River and its Tributaries, and for other Purposes."

In the great flood of 1927, the Atchafalaya River overflowed an estimated 2,419,000 acres of land lying between the latitudes of Old River and Morgan City and the approximate longitudes of Baton Rouge and Lafayette. With the construction of the East and West Atchafalaya Basin Protection Levees, the area subject to 1927 flood conditions would be confined to the acreage falling within the floodways, 860,000 acres, over much of which flowage easements have been secured.

Red River backwater

A large productive area known as the Red River Backwater Area, located just above Old River and west of the Mississippi, is subject to yearly backwater effects from the Red River and from the Mississippi River via Old River. With a stage of 56.4 on the Red River Landing gage in 1945, an estimated 2,600 square miles were inundated in this area. Some remedial measures have been taken, such as construction of a low levee along the north bank of the Red River between Black Hawk and Acme and up the east bank of the Black River, to protect a portion of this basin, but much greater measures are required to afford protection to the area as a whole. The capacity of impoundage of this important area is listed in Table 28, "Red River Backwater Area."

Sedimentation

Leveed reaches. Since confinement of the Atchafalaya River within levees, accretion along the bank has been of inconsequential magnitude while scour of the channel has been great.

Accretion between the natural riverbanks and the levees amounted to an estimated 18,000,000 cubic yards in the period 1932 to 1950 and represents an average fill of three-quarters of a foot.

Channel scour followed initial construction and extension of the confining levees. The progressive results of confinement were higher flood stages, steeper water surface slopes, greater velocities, channel scour and enlargement, and eventually increased discharge capacity and a reduction in water surface slopes. The latter phase of this progression is illustrated by Plate B91, "Water Surface Profiles for 350,000 c.f.s." The changes in channel area are shown by Table 45, "Comparison of Cross-Section Areas by Reaches for Period 1880-1950, Atchafalaya River from Head to Mile 54.3," and Plate B98, "Comparison of Cross-Section by Reaches and Progress of Levee Construction."

An estimated 254,000,000 cubic yards of material was removed from the river channel between 1932 and 1950. Of this amount, approximately 22,250,000 cubic yards is attributable to dredging, the remainder to river action.

Atchafalaya Basin. Sedimentation in the Atchafalaya Basin commences below the lower limit of influence of the Atchafalaya River levees. The construction of the levees along with the removal of the raft in the Atchafalaya River resulted in rapid enlargement of the channel and marked increase in the velocity of discharge. The efficiency of the river as a sediment carrier has increased also, contributing not only material carried in suspension from the Red, Mississippi and Old Rivers but providing Atchafalaya River material which is carried down into the Atchafalaya Basin.

In meeting the delta at the end of the leveed reaches, the channel gradually deteriorates and is dissipated into a number of inefficient streams.

The Atchafalaya River is now silting up its lower basin preparatory to pushing its channel to the Gulf of Mexico. Studies of surveys since 1916 indicate that such a channel is being developed at a rate of about one-half mile per year. Continuation of this rate will provide an efficient channel to the Gulf of Mexico by about 1985 or 1990.

Comparisons of surveys for the 18-year period from 1932 to 1950 indicate deposits in the basin below the levees amounting to an approximate average height of 3.3 feet. The actual 1950 heights over base surveys of 1932 supplemented by surveys of 1934 and 1941 are shown on Plate B74, "Lower Atchafalaya Basin, Height of Fill, 1932-1950."

From Plate B74 it will be noted that the greatest heights of fill occur in the area immediately below the ends of the levees, and in the Grand Lake area at the lower end of the Atchafalaya Basin.

The total volume of fill in the basin from 1932 to 1950 amounted to about one-and-one-half-billion cubic yards. Of this amount, over one-billion, one-hundred-million cubic yards were deposited in the area from the ends of the levees to upper Grand Lake near 30° latitude. Three-hundred-and-thirty-million cubic yards were deposited in the Grand Lake area to the north end of Cypress Island, with the remainder in the Six Mile Lake area.

Contributing to sedimentation in the basin are deposits from suspended sediment load estimated at over a billion cubic yards for the 18-year period, material in the amount of three-hundred-million yards scoured from the Old River and Atchafalaya River and basin channels, and the remaining two-hundred-million cubic yards attributable to unmeasured bed load.

The annual contribution of suspended sediment load and future trend of this load to volume of deposits in the basin are shown on Plate B100, "Deposits in Atchafalaya Basin from Suspended Sediment, 1932-1950."

In considering sedimentation in the basin a number of assumptions were made. Only four complete sets of suspended sediment measurements were obtained for this study. The mean of the concentrations at Simmesport, La., was assumed to reflect the average at the upper end of the basin. The difference between the concentration at Simmesport and the weighed average at Berwick Bay and Wax Lake Outlet was considered the loss due to deposition in the basin. From the mean annual discharge at Simmesport and an estimated density of 70 pounds per cubic foot, dry weight, the volume of deposition was computed.

The bed material samples secured for this study are so few in number as to preclude any engineering interpretation of results other than to indicate the composition of the material in the bed at a particular location, and its progressive variation in the course of the stream. Where possible and practicable, the 1951 samples were secured at 1932 locations for purposes of comparison. Results of any such comparison, however, should not lead to any hasty conclusions as the nature of the bed material along the bottom may vary considerably over a few hundred feet. The 1951 locations of samples may differ a few tenths of a mile from the 1932 locations; and both the 1951 and the 1932 sets of samples were secured from the thalweg of the stream which may have shifted considerably in the traverse section. The samples do not necessarily represent material which was in transportation since they were scooped off the bottom. In addition, material found at one stage may be different from that which would be secured at other stages.

The total volume of material from Old River and the leveed section of the Atchafalaya River was considered to have been deposited entirely in the basin. The portion of this material which may have been measured as suspended load at Simmesport is considered negligible. This is in view of the fact that a considerable length of the Atchafalaya River lies below Simmesport and at times when scouring is taking place suspended sediment concentrations in the river at the end of the levees would probably be much greater than that measured at Simmesport. Also, material transported as bed load was not analyzed, as was all bed-load material in continuous transport from the Red and Mississippi Rivers. This latter material is commonly estimated as a fraction up to 25 percent of the suspended load. On the basis of the assumptions used in this study, bed load would amount to about 20 percent of the suspended load.

Not neglected in the above considerations was the settlement, or consolidation, of materials deposited prior to 1932, and its effect on the apparent volume of the recently deposited material. This settlement was estimated at 5 percent of the height of the overlying deposit. Since the average height of fill was slightly over three feet, the settlement would amount to a little more than one-and-one-half inches. Converted to volume, the figure would be negligible compared to changes in apparent volume resulting from the choice of different density values.

In computations involving volume-weight ratios, the value of 70 pounds of dry material to 1 cubic foot of deposit was selected.

The exposed coarse material at the upper end of the basin was estimated at 85 pounds of dry material to 1 cubic foot of deposit. From this value it is reasonable to assume that the density of the deposited material drops gradually to extremely low values in the lower end. Undisturbed borings of submerged deposits in the latitude of Morgan City gave a value of 42 pounds per cubic foot. The value of 70 pounds per cubic foot for converting units by weight into units by volume was selected by the U. S. Department of Agriculture in studies of numerous Texas reservoirs. The value was also used as a conversion unit in sediment studies by the Arkansas-White-Red Basins, Federal Inter-Agency Committee.

Salt water intrusion

Fairly continuous records of salinity since 1936 are available for certain key stations in the Lower Atchafalaya Basin and the adjacent coastal area and a number of intermittent records are available at various other scattered locations. Locations of sampling stations are shown on Plate B40. Examination of the over-all data reveals that salinities in the coastal area adjacent to the Atchafalaya Basin and for a considerable distance to the westward thereof are controlled to a great extent by outflows from the Atchafalaya Basin. During flood periods salinities in the subject coastal area are very low. As the discharge decreases in the low-water season, salt water from the Gulf moves inland under the action of wind and tides, the intrusion effects continuing to increase as the low-water season is prolonged. Intrusion effects diminish with increased distance from the Gulf and progression inland is more rapid in deeper waterways. Intrusion under ordinary low-water conditions appears to be negligible in the shallow waters of Six Mile Lake, low-water salinities in the lower portion of Six Mile Lake being generally no higher than the mean salinities at upriver tributary stations. Exceptions to this rule may be experienced temporarily during extreme Gulf tides associated with hurricanes.

Discussion

Flood control

The Atchafalaya River has been the subject of numerous studies and reports. The enlargement of the river has caused apprehension that the Mississippi River channel would deteriorate to a serious extent below Old River. This apprehension has led to proposals for the separation of the two streams. A complete separation is, however, open to the serious objection that it would greatly increase the menace of Mississippi River floods below Old River.

Fears for the deterioration of the Mississippi River channel have even extended to the belief that the main river might ultimately abandon its present channel and adopt that of the Atchafalaya. To prevent the further enlargement of the Atchafalaya channel, two sills were placed across the river at Simmesport and an unsuccessful attempt was made to divert the Red River back into the Mississippi through the Upper Old River channel by a sill in Red River.

The removal of the Atchafalaya River raft during the period 1840 to 1861, the extension of the Atchafalaya River levees, and the channel dredging in the Atchafalaya River and Basin from 1932 to 1950 have resulted in considerable enlargement in the Atchafalaya River. The reasons for this enlargement are readily apparent. The removal of the raft increased the capacity of the existing Atchafalaya channel. The discharge of the river consequently increased and the development and extension of the existing Atchafalaya levee lines were the natural result. In its lower reaches the river, in its natural state, lost itself in a maze of tortuous waterways and tidal lakes whose channels had poor hydraulic characteristics. The levee lines have, however, confined the increased discharge of the river to one channel throughout the length of these lines. The enlargement of that channel was the inevitable result.

Below the lower limit of the Atchafalaya levee influence, silting is taking place in the leveed Atchafalaya Basin even though extensive dredging has been prosecuted in that area in the interest of flood control for the past eighteen years. The silting is more extensive now than before the channel enlargement permitted a marked increase in the volume of Atchafalaya discharge. The Atchafalaya presents an interesting study in the development of an alluvial stream. The river is now silting up the existing Mississippi River delta which it must cross before it can push its own channel to the sea and undertake the construction of its own delta. At present the flow of the Atchafalaya is generally dissipated in a network of inefficient channels in the lower portions of the basin. The Atchafalaya Basin main channel, constructed and enlarged between 1932 to 1941, provides the most efficient outlet of the Atchafalaya River to Grand and Six Mile Lakes. When, however, this sedimentation has raised the surface of the basin to a sufficient elevation, further development of the main channel by excavation and dikes will be required if an efficient outlet to the Gulf is to be provided and abnormal flood stages are to be precluded.

Comparative surveys extending from 1882 to 1950 indicate that the Atchafalaya River is actively engaged in pushing an efficient channel through the basin to the Gulf of Mexico. This regimen involves first the deposition of a sedimentary floodplain and then cutting a channel across it. The trend to steeper slopes in the basin as a result of silting is expected to reverse as the efficiency of the new channel increases and will eventually result in lesser slope being required. Studies of surveys since 1916 indicate that such a channel is being developed at a rate of about one-half mile per year. Continuation at this rate would provide an efficient channel to the Gulf of Mexico by about 1985 or 1990.

The effect of the Atchafalaya enlargement upon the Red and Mississippi Rivers may be summarized as follows. The removal of the raft and the extensive development of the Atchafalaya levees, accompanied by channel improvements of the Atchafalaya River and Basin, have caused an enormous enlargement of the channel and discharge capacity of the Atchafalaya River. Notwithstanding the enlargement of the Atchafalaya, however, the lower 35 miles of Red River and the Mississippi River channel above Old River have remained comparatively stable, whereas deterioration in the Mississippi River channel below Old River has not been excessive up to this time.

Navigation

The Atchafalaya River is a large stream with dimensions adequate for barge traffic throughout most of its length. Of the 123 miles between Morgan City and the junction of the Mississippi and Old Rivers only about ten miles in Grand and Six Mile Lakes require dredging to attain a low-water navigation channel 12 feet in depth below mean low water on a bottom width of 125 feet. This route saves 176 miles one way, and as much as 3-1/2 days per round trip between southeastern Texas and Upper Mississippi Valley points when compared with the route via Harvey Lock, and eliminates the lockage required at that point.

The Plaquemine-Morgan City Alternate Route is not used, waterway operators explain, because the tortuous channel is too difficult for modern integrated tows to negotiate. Enlargement to its authorized dimensions, 12 feet by 125 feet, extension to Port Allen, and construction of a lock at that point will revive its use to a large proportion of the total south Louisiana traffic. This route is shorter than the Harvey Lock route by 150 miles.

Navigation interests have pointed out the economic need for maintaining a low-water channel through the shoaled areas in Grand and Six Mile Lakes. They have informally stated that the time-distance savings of the route will have the effect of increasing the carrying capacity of their existing towing equipment by as much as ten percent. This is an important factor from the point of view of national defense, since the current national emergency has imposed demands on the barge lines beyond their present abilities to meet.

As a result of rapid sedimentation in Grand and Six Mile Lakes since the commencement of flood control activity in the basin in 1930, the high-water gage readings at Atchafalaya, La., have been steadily increasing with relation to those at Simmesport. This has led the spokesman for the Atchafalaya Basin Levee Board and the engineers representing the four railways crossing the river to favor proposed navigation improvements as an aid to flood control measures.

Although the upper reaches of the Atchafalaya River are enlarging, the discharge capacity of the lower reaches has not increased proportionately because of the accretion in Grand and Six Mile Lakes, see Plate B75. Between 1930 and 1950 the delta in Grand Lake along the Atchafalaya Basin main channel has advanced downstream a distance of approximately 24,000 feet, and is now about 2500 feet above Myette Point Cut at Mile 95.2. Accretion studies of these lakes, Plates B74 and B75 and B25 through B27, show that they are silting very rapidly and will eventually be completely filled. When this occurs, the Atchafalaya River by reason of its large discharge will develop a natural channel of adequate depth in these reaches. Development of the channel can be facilitated by systematic dredging and closure of extraneous channels at the proper times. During this development period the shoal reach below the end of the developed channel will continue to preclude use of the Atchafalaya River for commercial navigation during the low-water season. Provision of a navigation channel is considered desirable and such a channel will serve to facilitiate and expedite ultimate development of an adequate flood channel to dispose of the ever-increasing flood flow in the Atchafalaya Basin.

APPENDIX C

EFFECT OF ENGINEERING WORKS ON THE DEVELOPMENT OF THE ATCHAFALAYA RIVER

PREPARED IN

OFFICE OF THE PRESIDENT
MISSISSIPPI RIVER COMMISSION
CORPS OF ENGINEERS, U. S. ARMY

CONTENTS

APPENDIX C

EFFECT OF ENGINEERING WORKS ON THE DEVELOPMENT OF THE ATCHAFALAYA RIVER

Throughout the known history of the river, the Atchafalaya River and Basin have formed an important outlet for floodwaters from the Mississippi River. In its early history, the Atchafalaya was a small, drift-choked stream and flow entered the basin mainly overbank during times of flood.

The change in the Atchafalaya River from its original condition to its present well-defined deep channel through over half the length of the basin was brought about mainly by flood control and navigation works constructed by man, which have operated generally to assist natural forces in the development of the river channel. While some of these works did not immediately affect its capacity, and in fact did at some stage of development reduce the diversion into the basin, the over-all result has been a progressive enlargement of the channel to a point where the diversion of floodwaters is now greater than at any time in its history.

The first comprehensive survey of the Atchafalaya River was made in 1880-81, and the history of development prior to that time must depend on such maps as are available and on statements that have been recorded in various reports on the river and basin.

The earliest map available at the confluence of the Red, Atchafalaya, and Mississippi Rivers was made by a member of De Soto's expedition in 1578; it is said that succeeding maps show that no material change took place before 1831 when Shreve's Cutoff was made. Plate B2 of Appendix B shows the relationship of Old, Red, Atchafalaya, and Mississippi Rivers, 1805-1950.

Shreve's Cutoff was made primarily for the benefit of navigation on lower Red River, where the channel was deteriorating from deposits at its mouth. The cutoff was not entirely successful in accomplishing its purpose. While it did relieve the situation in Red River, subsequent filling in the old bendway (now called Old River) transferred the navigation difficulties from Red River to Old River.

In 1847 Raccourci Cutoff was made in the bend immediately below Shreve's Cutoff in an attempt to aid navigation in Old River. It is said that this operation increased the rapidity of filling in Old River rather than aiding navigation.

Atchafalaya River Raft

Shreve's Cutoff did accomplish an important change in the conditions at the head of the Atchafalaya River which allowed subsequent improvement of that stream. Prior to the cutoff the Atchafalaya River flowed directly from the apex of an abrupt bend of the Mississippi River, which condition made it the recipient of most of the floating drift coming down the river during floods. The results were that large rafts formed in the Atchafalaya River, choking off the flow and hindering its development. The cutoff eliminated the diversion of drift into the river and thus paved the way to the subsequent removal of the raft. The following is quoted from the Report of the Mississippi River Commission, November 1881, page 130:

> "Darby, in his Geographical Description of Louisiana, states: 'The Atchafalaya was first obstructed by timber in 1778.' In Ellicott's journal we find that 'this branch (the Chafalia), notwithstanding its magnitude, is not navigable to the Gulf of Mexico, owing to the immense floating bridge or raft across it, of many leagues in length, and so firm and compact in some places that horses and cattle

are driven over on it. This surprising bridge or raft is constantly augmenting by the trees and rubbish which the Chafalia draws out of the Mississippi.'

"Major Stoddard took possession of Upper Louisiana in 1804, under the treaty of cession. He was stationed about five years on the Lower Mississippi, and six months on the Red River. He stated that 'the channel of the Chafalia, a few miles only from the head of it, is completely obstructed by logs and other material. Were it not for these obstructions, the probability is that the Mississippi would soon find a much nearer way to the Gulf than at present, particularly as it manifests a constant inclination to vary its course.'

"And again, 'This outlet (Chafalia), in leaving the Mississippi about 3 miles below Red River, is nearly 200 yards wide. In low-water it is about 18 feet, and in high-water about 30 feet in depth. Thirty miles from the Mississippi it is obstructed by a raft of wood, bound together by a heterogeneous mixture of ligneous and other matter. In the course of 20 miles the navigation is choked by ten or twelve similar rafts, and it is calculated that the aggregate obstruction occasioned by them is not less than 9 miles. Some of them form good bridges, and are passable at all seasons. Many of them are covered with willow trees, and a considerable portion of them are 10 inches in diameter. These rafts rise and fall with the water, and are therefore justly termed floating bridges. Below the rafts the Chafalia affords a beautiful sheet of water at least as far down as Cow Island, from 75 to 150 yards wide, and from 25 to 30 feet deep in the dry season. The current of the Chafalia is quite gentle, till it is joined by the Plaquemine, 160 miles from the outlet of the Mississippi, when its velocity is considerably increased.'

"Finally, Darby writes in 1817:

" 'On the subsiding of the spring floods, I have seen the water flowing from the Atchafalaya into the Mississippi. This circumstance is very contrary to the common opinion on the subject, but it is true. I was witness to the effect in the fall season of three years ago. Indeed, so completely is the communication cut off at low-water between the two rivers, that very often a common canoe cannot be taken from one to the other.' "

Enlargement of the Atchafalaya River, 1840-1881

The State of Louisiana commenced work on removal of the Atchafalaya River raft in 1840 and the channel began almost immediately to widen and deepen. The enlargement between the years 1840 and 1881 can be followed only in a general way because of the scarcity of information available. In one report it is stated that during the low water of 1839 a person could walk across the stream at its head by means of a plank 15 ft. long. In 1850 Professor Forshey stated that from reported sounding he found a mean high-water depth at the head of about 50 ft., with a width of 730 ft. In 1879 Major Benyaurd found extreme low-water depths of 85 ft. and a width of 900 ft. near the head of the river.

Cross sections taken near the head of the Atchafalaya River during the various surveys up to 1879 are shown in the following tabulation:

Date of Survey	Area of Cross Section sq. ft.	High-Water Width ft.	Maximum Depth ft.	Increase in Area sq. ft.	Percent of Increase
1851	24,400	730	52	--	--
1859	28,700	830	63	4,300	17
1874	39,160	891	114	14,760	61
1879	52,100	940	130	27,700	113

In the 1881 report of the Mississippi River Commission a comparison of survey data taken in 1874 from the head of Butte La Rose, a distance of 79 miles, indicates a general widening and deepening of the stream. The average widening during the period was about 65 ft. with some few cross sections showing a loss in width. The average of the maximum depths of cross sections below the 1874 high-water elevation was 43.5 ft. in 1874 and 58 ft. in 1881.

An examination of 1881 cross-sectional areas, shown in Table 45, Volume 3, averaged for 5-mile reaches except for a 3.3-mile reach at the upper end, shows bankfull areas of from 50,000 to 58,000 sq. ft. in the upper 18 miles of river; 30,000 to 38,000 sq. ft. in the next 20 miles; and 21,000 sq. ft. for the next five miles. Low-water areas were not as uniform as were the bankfull cross sections in the lengths of river compared but generally ranged from 18,000 to 23,000 sq. ft. in the upper 18 miles and from 12,000 to 18,000 sq. ft. from Mile 18 to Mile 43. The levees along the Atchafalaya River prior to 1881 extended only a short distance below its head and flood flows were more or less free to flow overbank below them. The larger section at the upper end of the river at this time would be expected as there was some confinement by levees and the channel near the head was required to carry more flow than the reaches below where water escaped overbank into the adjoining basin. The progress of levee extension is detailed in Table 29, Volume 3.

Development in Old River

In Old River following Shreve's Cutoff in 1831 there was rapid filling in both the upper and lower arms of Old River. By 1839 navigation difficulties were being experienced, navigation using the upper arm of Old River to Red River. In 1845, 1846, and 1847 navigation was virtually suspended during the low-water season. By 1866 the Lower Old River channel was completely closed at its mouth by deposits and had a heavy growth of timber across it. The upper channel at that time was very narrow and shallow. In 1872 the river forced a channel through the narrow strip of land that obstructed the lower channel of Old River, and since that time this channel has been used as the navigation route between the Mississippi and Red Rivers. In 1877 navigation had become so difficult in Old River that the State made an appropriation to keep it open, and the following year the Government employed two tugs and a steamer for a month for the same purpose. In 1888 navigation was cut off from Old River for 120 days. A report made in 1907 states that since 1893 continuous navigation had been maintained in Old River and that since 1900 no dredging had been necessary at several former shoal points along the channel, dredging being confined to the bar at the mouth of Old River. It also states that in the 14 years preceding 1893 the attempt to maintain low-water navigation had failed eight times. Dredging of the bar at the mouth of Old River to maintain low-water navigation was necessary occasionally until comparatively recently.

The filling of Old River probably had very little effect on the early development of the Atchafalaya River. It is reasoned that had additional capacity been necessary at the time, to supply water to the Atchafalaya, not so much filling would have taken place. Later, as the capacity of the Atchafalaya River increased, Old River began to enlarge also and it is now enlarging at a rate comparable to that of the Atchafalaya. Comparative cross-section data from 1894 are shown in Table 44, Volume 3. It might be said that Old River is now delaying the development of the Atchafalaya by reason of the fact that it has to enlarge to furnish the water demanded by the Atchafalaya at almost all stages.

Mississippi River Levees

The construction of the Mississippi River levees has raised flood stages in the vicinity of the head of the Atchafalaya River by confining the flood flows from above, and hence has increased the slope to some degree in the Atchafalaya River. This has no doubt contributed something to its development. Probably the most important effect has come in comparatively recent years as a result of raising and strengthening the levees, as during the early development practically every major flood crevassed the levees, and generally produced flood stages lower than they would have been had the levees held.

Mississippi River Below Old River

A matter of interest and concern in connection with the development of the Atchafalaya River is the effect on the Mississippi River below Old River. Engineering and geological conclusions as to the development of prior major changes and the more recent experience with the development of artificial and natural cutoffs and the passes at the mouth of the river support the theory that once the diversion obtains a discharge sufficient to start the main channel below to adjusting its cross section to the lesser discharge it is required to carry, the rate of improvement of the distributary is accelerated, which in turn results in an increased rate of deterioration in the main channel.

In this connection, discharge measurements were plotted against stage at Red River Landing for each year in which discharge records were available, and a comparison of capacity was made on the basis of stage-discharge relation. In making this comparison, discharges measured for high floods prior to 1893 were not used because of the fact that the Morganza crevasse, a short distance below Red River Landing, was open during those floods. There is not enough information available to definitely determine the effect of the crevasse on the stage-discharge relation for each flood at Red River Landing. Some idea of its effect can be gained by an examination of the discharge measurements of 1890 where on 18 April at a stage of 47.8 the discharge was 1,283,000 c.f.s. and on 1 May for a stage of 47.4, 1,418,000 c.f.s. was measured, and the discharge increased to 1,453,000 c.f.s. on 7 May at a stage of 47.2 ft. Crevasses at Morganza occurred on 21 and 22 April. These two crevasses along with other crevasses in the vicinity that occurred about the same time discharged more than 250,000 c.f.s. in 1890.

Table 1, following, shows the rising and falling stage for each year for selected discharges where sufficient information was available to establish it. The stages shown were interpolated from the plotted points and an average was used where the points were grouped. In general, the table shows as much as 4- or 5-ft. variation in stage for the same discharge under similar conditions; i.e., rising or falling, for overbank flow and somewhat less for within bank flow. In some instances there is as much as 2- to 4-ft. variation in consecutive years. The tabulation presented might be interpreted to indicate that there was some deterioration in the flood-carrying capacity of the river between the early records and about 1916, a leveling off to about 1929, and an increase in capacity since that time. Such a condition is not unusual on the river as slight changes in local flow conditions can change the stage-discharge relation at any given point. The tabulation shows that the stage-discharge relation at Red River Landing is now approximately the same as for the earliest comparable record. To further substantiate this, Plate C1, Appendix C, was prepared showing the actual discharge measurements for 1893, 1911, 1912, and 1950, plotted against the stage at Red River Landing. Practically all of the points for the earliest years fall within the rising and falling loop formed by the 1950 measurements, and if measurements for either year were used to determine an average rating curve, it would vary from a 1950 average curve generally only a fraction of a foot.

The apparent loss in flood-carrying capacity up to 1916 and the gain since 1929 cannot be attributed to the change in capacity of the Atchafalaya River, as it has

Table 1

STAGES AT RED RIVER LANDING FOR SELECTED DISCHARGES

Selected Discharge, c.f.s. at Red River Landing	Year	Stage at Red River Landing, ft. Rising	Stage at Red River Landing, ft. Falling
1,400,000	1950	51.7*	53.6*
	1945	52.0*	55.5*
	1937	52.8*	55.0*
	1927	56.2*	-
	1912	52.4*	-
1,300,000	1950	47.8	52.4
	1945	48.0	52.5
	1944	50.5*	-
	1937	50.2	54.5
	1929	52.5*	-
	1927	54.0	-
	1922	52.4*	-
	1916	52.2*	-
	1913	50.4*	-
	1912	48.8	52.5
	1897	50.4	-
	1890	48.2†	-
1,000,000	1950	39.4	45.8
	1949	41.0	44.8
	1946	43.0*	45.5*
	1945	39.4	45.7
	1944	42.0	45.8
	1943	40.0	42.0
	1939	43.2	46.2
	1938	44.6*	-
	1937	41.9	46.2
	1935	-	46.3
	1933	-	47.9*
	1929	43.8	-
	1913	-	47.0
	1911	42.6*	-
	1904	43.6*	-
	1893	-	43.1
	1892	40.0	-
	1890	41.3	-
700,000	1950	31.8	35.5
	1949	32.8	35.8
	1948	32.8	37.8
	1947	35.4	37.2
	1946	32.6	35.2
	1945	30.6	36.0
	1944	-	34.8
	1942	32.3	34.7
	1940	34.3	35.3
	1938	30.7	35.6
	1937	30.8	36.5
	1936	33.2	34.7
	1932	34.0	36.6
	1892	32.8	-
	1889	-	32.0
	1885	-	33.2
	1882	31.2	33.3
500,000	1950	-	28.0
	1949	23.2	26.6
	1948	20.8	26.2
	1947	27.6	31.1
	1946	26.0	-
	1945	22.3	27.7
	1944	-	26.4
	1943	23.2	-
	1942	23.5	-
	1941	25.0	26.1
	1940	24.6	27.8
	1939	-	27.4
	1938	-	26.3
	1937	-	27.0
	1936	23.4	25.8
	1935	-	26.7
	1885	22.0	-
	1882	-	26.0

* Near crest stage.
† Immediately prior to Morganza Crevasse.

been shown that the flood-carrying capacity of the Atchafalaya was reduced up to about 1927 and has been increasing since that time.

In the period July 1938 to March 1940, about 17,000,000 cubic yards of improvement dredging were done in the three-mile reach below Red River Landing. The purpose of this dredging was to alter the alignment to some extent to improve a navigation condition caused by the development of a sharp bend along the right bank of the river. The dredging developed the channel along the opposite bank of the river and relieved the bad navigation condition. The effect of this dredging on the stage-discharge relation at Red River Landing was not particularly noticeable; possibly there could have been an improvement that is masked by the normal variation in this relationship. At any rate there is no indication that there was any change in normal conditions as a result of this work.

Table 41, Volume 3, shows the areas of cross sections by approximately 5-mile reaches from Mile 277.1 to Mile 318.6 above the Head of Passes from 1882 ~~to 1950, and Table 2, herein, shows the variation in areas between the surveys~~ and various comparisons of areas. Plates B11 through B14, Appendix B, show Mississippi River cross sections for this vicinity.

In using these data to indicate the effect of improvement in the capacity of the Atchafalaya on the area in the Mississippi River below Old River, it is believed advisable to consider only the period of record during which the improvements took place. The period prior to 1880 cannot be considered on account of lack of data. Other studies have indicated that there was a decrease in capacity of the Atchafalaya for flood stages from the 1880's up to about 1927, and for stages around bankfull the decrease stopped probably around 1912. Very little information is available on low-water discharges but the indication is that there was a progressive improvement in the low-water capacity since the earlier measurements. Probably the nearest survey to the average time at which the increase in capacity of the Atchafalaya River began following the levee construction along that river is the one labeled 1913-15, 1921-22 in Table 41, Volume 3.

A comparison of areas between this survey and the 1950 survey indicates that there has been a decrease in cross-sectional areas of the Mississippi River below Old River during that period for both bankfull and low-water stages. The data also show a decrease in area for the two reaches immediately above Old River; i.e., reaches 2 and 3.

The cross-sectional areas at low water in 1950 of reaches 5, 6, and 7 were less than shown for any previous survey and in other reaches were greater than the least prior area. The 1950 bankfull areas were less than for any previous survey in reaches 3, 4, 5, 7, and 8 and were greater than the least prior area for other reaches. It might be said that the 1950 areas were generally smaller below Old River in 1950 than for any previous survey. Above Old River smaller areas had been measured in previous surveys. The difference in some cases is small and comparison of future survey areas may indicate that the river has restored these apparent deficiencies.

There is some indication from these comparisons of areas that a trend toward deterioration has begun in the Mississippi River below Old River. This deterioration has not been sufficient to cause any reduction in the discharge capacity of the Mississippi River below Old River. Close observation of the reaches shown in the comparison should be maintained in order that positive recognition or disproof of deterioration can be established.

Atchafalaya River Levees

In 1881 a line of levees extended from Simmesport to Melville along the west bank of the Atchafalaya River and about 13-1/2 miles below the head of the river on

Table 2

CHANGE IN AREA OF CROSS SECTION OF THE MISSISSIPPI RIVER
BY REACHES IN THE VICINITY OF OLD RIVER

Reach	River Mileage above Head of Passes	1882 to 1895	1895 to 1913-15 and 1921-22	1913-15 and 1921-22 to 1932-33	1932-33 and 1935 to 1937	1937 1938	1938 to 1950	Net Change 1882 to 1950, sq. ft.	1912-13 1922-23 to 1950	Net Change Lowest Prior Year to 1950
					Change in Area sq. ft. below Mean Low Water					
1	318.6-313.6	+2130	+9670	+5350	+8780	-2380	-1880	+21670	+9870	+21670
2	313.6-308.5	-25320	+20030	-3710	+4380	-3830	-8370	-16820	-11530	+8500
3	308.5-303.4	+6920	+21610	-8440	-2650	-3030	-3310	+11100	-17430	+4180
4	*303.4-297.6	-12090	-7800	-14490	+8950	+860	-3240	-27810	-7920	+6570
5	297.6-292.4	-13580	+980	-12780	-2730	+5330	-9070	-30850	-19250	-3740
6	292.4-287.2	-13390	+5910	-12970	+4220	+570	-9340	-25000	-17520	-4550
7	287.2-282.3	-3910	-5610	+2120	-2840	-1060	-1130	-12430	-2910	-1130
8	282.3-277.1	-27220	+5660	+910	+240	+1600	-7650	-26460	-4900	+760
					Change in Area sq. ft. below Bankfull Stage					
1	318.6-313.6	-4940	+2970	+1550	+15510	No	-12860	+2230	+4200	+7170
2	313.6-308.5	-29150	+23500	-5410	+7540	survey	-4390	-7900	-2260	+21250
3	308.5-303.4	-5320	+8810	-1450	+3850	†	-12560	-6670	-10160	-1350
4	*303.4-297.6	-10980	+17880	-11750	+5280		-13060	-12630	-19530	-1650
5	297.6-292.4	-15960	+7420	-7710	-8170		-9060	-33470	-24930	-9050
6	292.4-287.2	-17930	+10570	-11030	+7490		-5760	-16660	-9300	+1730
7	287.2-282.3	-6630	-29700	+7910	-1420		-18430	-48270	-11940	-11940
8	282.3-277.1	-34470	+3580	+3600	+2990		-10590	-34890	-4000	-420

* Old River at about Mile 302.0.
† 1938 Survey—cross-sectioned below low water only.

the east bank. These levees had been built by private interests and were deficient in both grade and section. They were raised, strengthened, and extended gradually to improve and increase flood protection in the basin and consequently increased the confinement to the channel of the Atchafalaya River. Table 29, Volume 3, and Plate C2, Appendix C, show the progress of the levee extensions.

The building of the levees along the Atchafalaya River contributed probably more than any other construction to its development. Table 45, Volume 3, and Plate B98 show a comparison of the bankfull and low-water cross sections by reaches from 1880 to 1950. Plate C2, Appendix C, shows the enlargement of the bankfull cross sections by reaches from 1880 to 1950.

Between the years 1880 and 1904 the average bankfull area in the reach from Mile 3.3 to 8.1 enlarged about 3,000 sq. ft., from Mile 8.1 to 13.1 the area decreased about 1,000 sq. ft., from Mile 13.1 to 18.1 it increased about 7,000 sq. ft., in the next four five-mile reaches to Mile 37.9 the average bankfull area increased from 17,000 to 20,000 sq. ft., and in the reach from Mile 37.9 to 42.9 increased about 10,000 sq. ft. No data were available for 1880 on the other reaches above Mile 58. During this period the levees were extended on the east bank from Mile 13.5 to Mile 43 and on the west bank from Mile 26 to Mile 36. The greatest increase in area during the period was in the reach affected by levee construction with a much smaller enlargement above the 1881 end of the east bank levee. It is interesting to note that the 1904 average bankfull area compared by reaches above Mile 32.9 varies from about 53,000 to 58,500 sq. ft.

Between 1904 and 1916 the enlargement above Mile 42.9 ranged from 3,000 to 10,000 sq. ft., and from about 21,000 to 22,000 sq. ft. in the next 10 miles, then dropped off to 11,000 sq. ft. in the next five-mile reach. During this period the levees were extended from about Mile 43 to Mile 44 on the east bank and from Mile 36 to 43 on the west bank. The greatest enlargement shown was immediately below the reaches affected by the levee extension during the period. Above the 1904 end of the levees there was a smaller but substantial enlargement in cross-sectional area of the channel.

Between 1916 and 1931 there was generally a small increase in cross section above Mile 37.9. The change in cross section varied from a small decrease in area in two reaches to about 13,000 sq. ft. increase in one reach; however, the increase in cross section of the other reaches in this length runs from 1,000 sq. ft. to less than 5,000 sq. ft. Below Mile 37.9 the increase in cross section varied from 13,000 to 19,000 sq. ft. The levees during this period were extended to about Mile 55 on the east bank with very little extension on the west bank.

Between 1931 and 1935 there were several surveys which show decreases in cross section as well as increases. However, the over-all increase amounted to from 8,000 to 14,000 sq. ft. in the upper 18 miles of the channel, practically nothing between Miles 18 and 38, and about 3,000 to 4,000 sq. ft. between Miles 38 and 58.

Between 1935 and 1945 there was an increase in area of cross section throughout the upper 58 miles of the Atchafalaya River amounting generally to from 10,000 to 15,000 sq. ft. in the various reaches.

Between 1945 and 1950 there was a general enlargement of from 8,000 to 12,000 sq. ft. throughout the leveed reaches of the Atchafalaya River.

The increase in cross-sectional area throughout the Atchafalaya River appears to be directly related to the construction of the levee system. Substantial increases in cross-sectional area advanced downstream rapidly with the extension of the levee system, and the confined flows more gradually enlarged the cross section where the levees already existed. There is evidence, not altogether conclusive, that the large floods caused most of the enlargement, especially in reaches where the levees had existed for some time.

Table 3, herein, showing the crest discharges available from discharge measurements and Table 4, following, prepared from stage-discharge curves showing the Simmesport stage for given discharges and for various years, were prepared to show the effect of the levees and channel enlargement on the diversion into the Atchafalaya Basin. The discharges, it should be pointed out, reflect the strength as well as the length of levees along the Atchafalaya River. Table 27 of Volume 3 lists the crevasses on the Atchafalaya River. The location as well as the number of crevasses during these floods had an effect especially on the crest flows of these floods so that the discharges do not represent the confined capacity of the river.

Table 3

OBSERVED CREST STAGE AND DISCHARGE AT SIMMESPORT
TABULATED IN THE ORDER OF STAGE

Year	Barbre Landing Stage, ft.	Simmesport Discharge, c.f.s.
1927	57.7*	460,000*
1945	55.1	660,000
1912	53.35	410,000
1937	53.4	470,000
1950	52.1	630,000
1916	52.0	390,000
1897	51.0	410,000
1903	50.2	380,000
1929	50.1	385,000
1890	49.7	480,000
1892	49.7	450,000
1944	49.0	440,000
1893	48.0	360,000
1908	48.0	320,000
1935	46.2	370,000
1891	45.6	320,000
1939	45.6	380,000
1938	45.3	370,000
1933	44.6	330,000
1943	44.0	430,000
1946	43.6	440,000
1906	43.3	270,000
1909	43.0	310,000
1898	42.9	260,000
1904	41.3	240,000
1928	41.0	290,000
1947	40.8	380,000
1911	40.2	210,000
1936	38.2	280,000
1940	37.0	280,000
1934	35.0	230,000
1889	33.6	130,000
1941	31.5	240,000

* Immediately prior to Melville crevasse.

Table 4

COMPARISON OF SIMMESPORT STAGE FOR A GIVEN DISCHARGE

Discharge, c.f.s.	Year	Simmesport Stage, ft.
450,000	1927	52.8
	1937	49.0
	1892	44.7
	1945	42.6
	1950	40.4
400,000	1927	50.8
	1912	49.7
	1897	48.8
	1937	45.4
	1892	44.6
	1944	43.0
	1945	39.4
	1943	39.0
	1950	36.6
350,000	1912-1927	47.4
	1897	46.4
	1893	45.6
	1913	44.7
	1892-1928	43.5
	1937	42.2
	1939	40.2
	1944	37.2
	1945	36.0
	1943	35.9
	1950	32.8
300,000	1912	44.2
	1893	43.4
	1927	43.2
	1892	42.9
	1891	41.2
	1928	39.6
	1937	37.3
	1939	35.3
	1945	31.9
	1950	29.0
250,000	1912	40.5
	1892	39.8
	1891	39.4
	1927	38.0
	1928	35.6
	1937	32.0
	1939	30.5
	1945	28.3
	1950	25.1

An examination of Table 3, Appendix C, which lists the crest discharge measurements for each year of record and the corresponding crest stage at Barbre Landing, indicates that for the higher floods there was a reduction in the capacity of the river for diversion into the Atchafalaya Basin, possibly to as late as 1927, and an increase in its capacity since that time. The 1927 flood, which was the highest of record, shows a crest discharge of 460,000 c.f.s., and a crest stage of 57.7 ft. immediately prior to the Melville crevasse. The 1890 and 1892 records show discharges of 480,000 and 450,000 c.f.s., respectively, for a stage of 49.7 ft. Allowing 20,000 c.f.s. per foot of change, the indication is that in the 1890 to 1892 period, a discharge equivalent to that of 1927 would have occurred at a stage approximately eight to nine feet lower. Similarly, after making allowances for the difference in measured discharge, the 1912 and 1916 measurements indicate that a flow equivalent to that of 1927 would have passed at a stage about two feet lower. The 1937 discharge information indicates about a five-foot improvement over 1927, and the 1946 data from 12 to 13 ft. lowering. ~~Discharge measurements made in 1950 indicate about two feet of~~ lowering in the stage-discharge curve since 1945.

Examining the foregoing Table 3 a little further for stages approaching bankfull it appears that there was not much change in capacity of the river channel at its head during the early period of levee extension. In 1898 a discharge of 260,000 c.f.s. occurred at a stage of about 42.9 ft. on the Barbre Landing gage while in 1906, 270,000 c.f.s. occurred at a stage of 43.3 ft. In 1928 a discharge of 290,000 c.f.s. was measured at a stage of 41 ft., indicating a lowering of from three to four feet since the early period. The 1940 measurements indicated possibly a 2-1/2-ft. lowering since 1928 and those of 1947 possibly an additional six to eight feet for equivalent discharge.

Table 4, Appendix C, taken from rating curves at Simmesport, shows stages at Simmesport for various years corresponding to a given discharge. These data, in general, confirm the observations noted in the preceding paragraphs from the tabulation of crest stages and discharges. This table shows that for a discharge of 450,000 c.f.s. the 1927 stage was about eight feet higher than the stage for that discharge in 1892 and that the 1950 stage is 12 to 13 ft. lower than 1927. This table also shows that as bankfull stages are approached the loss in capacity indicated for high stages during the early periods of record becomes less and less. For 400,000 c.f.s. the 1927 stage is about six feet higher than the 1892 stage for the same discharge; for 350,000 c.f.s. it is about four feet higher; for 300,000 there is practically no difference; and for 250,000 c.f.s. the 1927 curve is nearly two feet below the 1892 curve. Discharge information available does not allow as good a comparison for lower discharges but in general indicates a progressive increase in capacity for low water. The 1950 discharge curve indicates an improvement of 14 to 15 ft. in stage for the same discharge when it is compared with the worst condition noted above.

It will be noted that even as late as 1937 the stage for a given discharge in the Atchafalaya River for large floods was higher at Simmesport than the stage for the same rate of discharge in 1892. This fact led some comparatively recent writers to conclude that there was no trend toward an increased diversion through the Atchafalaya River. The great improvement in the capacity of the Atchafalaya River in the past 10 to 12 years, or even since 1927, forces revision of that line of thought.

Sill Dams on Atchafalaya River

In 1884 the Mississippi River Commission proposed that a series of brush dams be placed in the Atchafalaya River with the upper one below Bayou des Glaises and the others at intervals not exceeding one-quarter mile. The dams were to be built up to just below low water and with a sill not less than 300 ft. wide, up and downstream. Six dams were shown on the original plans. The purpose was to limit the flow in the Atchafalaya River to approximately the flood discharge of Red River.

Sill Dams No. 1 and No. 3 were constructed in 1888 and 1889, respectively, and were the only dams built. The locations of the sill dams are shown on Plate B16, Appendix B. The upper edge of Sill Dam No. 3 was 1,750 ft. downstream from the lower edge of Sill Dam No. 1. The dams were composed of willow mattresses three feet thick, covered with heavy layers of rock. They extended 304 ft. up and downstream and were built to within five or six feet below the zero of the Barbre Landing gage. The sill dams were widened in 1901, the upper one to 560 and the lower one to 440 ft.; and in 1903 the lower sill was widened to 560 ft. The final maintenance on these dams by the United States was done in 1920.

In 1926 the Louisiana Railway and Navigation Company placed a mattress 150 ft. wide across the river preparatory to building a bridge. This mattress overlapped Sill Dam No. 1 about 25 ft. and extended entirely across the river.

The 1927 flood caused general subsidence of the upper sill averaging about 9.1 ft. over a width of 560 ft., with a maximum change of 44 ft., and total destruction of the lower sill on the right bank above an elevation of 24 ft. m.g.l.

On pages 58 and 59 of H. D. 841, 63d Congress, second session, dated 19 March 1914 appears the following statement: "On the other hand, for several years prior to 1887 the Atchafalaya showed a tendency toward rapidly enlarging its cross section so that fear was expressed by many parties that the Mississippi would practically abandon its own course to the Gulf in favor of the shorter route via the Atchafalaya. In order to prevent such a change, which would have injurious effects to an extent that could not even be predicted, the Mississippi River Commission caused to be constructed two sill dams near the head of the Atchafalaya, at Simmesport. These were placed during the years 1887, 1888, 1889, and 1890, with further reinforcement in 1901, 1902, and 1903; the crests of the dams were placed 5 feet below the zero of the Barbre gauge, but there has been considerable settlement (which was anticipated), so that the crests are now 10 to 25 feet below the zero of that gauge. The effect of these sill dams has been to check the tendency of the head of the Atchafalaya to enlarge . . ."

Sill Dam No. 1 reduced the bankfull cross section approximately 13,000 sq. ft. and the low-water cross section about 11,000 sq. ft., and the reduction at Sill Dam No. 3 was presumably in that neighborhood.

Cross-sectional areas at Sill Dam No. 1 as shown in Table 30, Volume 3, show an area of 44,480 sq. ft. in 1888, and a low-water area of 7,240 sq. ft. The bankfull section increased to 50,800 sq. ft. in 1900, reduced to about 46,600 in 1904-05, then increased to 56,600 in 1925. The variation in area during the life of the dam was 12,000 sq. ft. at bankfull stage. The variation at low water was around 8,000 sq. ft. during the life of the dam.

Table 45, Volume 3, showing the cross-sectional areas averaged by reaches indicates a variation in area in the upper 13 miles of river of 8,000 to 10,000 sq. ft. for bankfull stages, and from 4,000 to 10,000 sq. ft. at low water between 1880 and 1931, with approximately 16,000 sq. ft. enlargement at bankfull between Mile 13 and Mile 18. Below Mile 18 the enlargement was considerably more, but the total area of the 1880 cross sections was less than above Mile 18. Levee extensions confined the flows progressively further downstream and increased scour action in the lower reaches.

The effect of the sill dams is obscured to some extent by the progressive levee extension on the Atchafalaya River during their life. However, an examination of the records indicates that the more logical conclusion is that the levee extensions at first reduced the capacity of the Atchafalaya River by greater confinement, and consequently reduced velocities and scour action in the upper reaches where the channel was relatively large. This retarded but did not completely stop enlargement of the upper reaches of the river. As enlargement of the newly leveed sections progressed, the increasing downstream capacity permitted resumption of the upstream enlargement in recurring cycles.

A channel obstruction with limited length in the direction of flow, such as is caused by a sill or submerged weir would, theoretically, increase the stage above it for a given discharge by an amount sufficient to produce the increased velocity through the restriction. If no other action took place, this would reduce the flow for a given stage above the structure. Where two outlets are involved and only one is so treated, it would theoretically decrease the flow in one and would increase it in the other. The effect would depend on the amount of constriction. However, in an erodible channel such as the Atchafalaya River, where the flow is sufficient to continue channel enlargement downstream in spite of the initial reduction in flow, stages would continue to lower downstream from the restriction and would allow a greater head and eventually more flow for a given stage upstream of the restriction. This process would continue until lowering downstream ceased, or until critical flow is produced at the weir.

In the case of the Atchafalaya River sill dams, neither of the above-mentioned limiting conditions existed during their life. There is no evidence that there was any considerable fall across the dams at high water and the reduction in cross section at bankfull stage resulting from the constriction of the sill dams was probably not more than 20 percent. On this basis it is concluded that the effect of the sill dams in limiting the flow of the Atchafalaya could have been only minor in nature.

Sill dams were placed in the passes of the Mississippi River at various times in an effort to control the flow through the passes. These dams did not reduce the cross section as much as did those on the Atchafalaya River and they were in general only 2-1/2 to 3 ft. thick. In 1876 sills were placed across Pass a Loutre and Southwest Pass, the two larger passes, in an effort to increase the flow in South Pass. There is no evidence that the sills were effective in this respect. In 1900 an additional sill was placed across Pass a Loutre in an effort to reduce the flow through the pass and to accelerate the closure of a crevasse. The discharge of the pass had been on the decline since 1891 because of the gradual closure of the crevasse and the effect of the sill was obscured for this reason. In 1907 and 1908 sills were placed across Cubits Gap and The Jump in order to keep these outlets from enlarging. These sills probably had no effect.

In 1910 the sill across Southwest Pass was removed to increase the flow in the pass. The flow in the pass continued to decline which indicated that the removal of the sill probably had no effect. In 1917 a sill was placed across South Pass to limit the flow through it. It was removed in 1934 because a large scour hole below it was endangering the stability of the banks. The removal of the sill did not affect the scour hole.

There is no clear evidence that any of the sill dams constructed at the passes of the Mississippi River accomplished the purpose for which they were designed.

There is no proof, either theoretical or in fact, to indicate that the sill dams constructed in the Atchafalaya River had anything more than a minor effect in limiting the discharge of that stream. There is no reason to believe that a similar construction at the present time would be effective. The construction of several sill dams spaced over a fairly long reach of river might slow up the enlargement of the Atchafalaya River. However, there is no basis for the design of such a system and no assurance that they would prevent the eventual capture of the Mississippi River by the Atchafalaya River.

Effect of Rising Stages at End of Atchafalaya River Levees in Reducing Intake of Water into Atchafalaya River

The 1950 flood reached a stage of 31-1/2 ft. m.s.l. at the end of the Atchafalaya River levees, about 1/2 ft. below the approved levee grade at this point. At Mile

42.9, near Krotz Springs, the stage was 38.7 ft. m.s.l., about 2.4 ft. below the approved grade. At Simmesport the stage was 54.1 ft. m.s.l., about 6.3 ft. below the approved grade. The discharge was about 620,000 c.f.s.

There has been a noticeable rise in backwater stage below the end of the Atchafalaya River levees. For nearly the same flow the 1950 flood produced stages varying from those of 1945 in a wedge shape, lower at Barbre Landing, about equal at Krotz Springs, and generally higher below Krotz Springs. In order to define the magnitude of this tendency, tabulations are presented, based on the well-defined, average stage-discharge relation at Simmesport, and the well-defined average stage relations, Simmesport to Atchafalaya, La. (which is located a few miles below the end of the Atchafalaya River levees). The following tabulation shows that for the same Simmesport stage, the discharge has increased with the passage of time since 1932, and the stage at Atchafalaya, La., has also increased:

Year	Simmesport Stage ft. on Gage	Simmesport Discharge 1,000 c.f.s.	Atchafalaya, La. Stage ft. on Gage
1932	47	402	24.5
1937	47	414	25.5
1945	47	534	27.5
1950	47	580	29.9

Since the relation of Red River Landing to Simmesport stages shows little or no tendency to change, the above means that for a given Mississippi River stage, more water will go down the Atchafalaya River and stages at Atchafalaya, La., as well as generally over the middle part of the basin will be higher. The following tabulation gives similar information from a different viewpoint, showing that for the same Simmesport discharge, the Simmesport stage has decreased with the passage of time since 1932, while the stage at Atchafalaya, La., has increased:

Year	Simmesport Stage ft. on Gage	Simmesport Discharge 1,000 c.f.s.	Atchafalaya, La. Stage ft. on Gage
1932	47.5	410	24.6
1937	46.7	410	25.4
1945	40.1	410	26.3
1950	37.1	410	27.3

This latter effect is due to sedimentation in the basin below the end of the levees. It is due principally to the building up of the natural levees along the banks of the channels, and to deposits of sediment in the form of "fans" at the termini of outlets branching from the natural levees. This is of course quite significant. But, in order not to exaggerate its importance, attention is called to the fact that the effect on extreme floods approaching project magnitude would be porportionately less. This is due to the fact that for very high stages the natural levees are ineffective in confining the flow, and water spreads over the whole basin, where sedimentation has been less than along the banks. The form taken by the sedimentation is illustrated by Plates B55 through B73, Appendix B.

Between 1945 and 1950, for a discharge of 600,000 c.f.s. past Simmesport, the Simmesport stage was reduced about two feet, while the stage at Atchafalaya, La., increased about two feet. Assuming the levees to be raised so as to remain confining, computations have been made to determine what the effect of a continued rise in the backwater stage would be in diminishing the withdrawal ability of the Atchafalaya. The computations first assumed the same discharge as occurred during the 1950 flood (620,000 c.f.s.) but meeting a higher backwater stage. Results were as follows:

(a) For a 5-ft. rise in backwater stage above the 1950 condition, the stage at Mile 42.9 near Krotz Springs would be raised 3.4 ft. The stage at Simmesport would be raised 1.2 ft.

(b) For a 10-ft. rise in backwater stage, the stage at Mile 42.9 near Krotz Springs would be raised 7.2 ft. The stage at Simmesport would be raised 3.1 ft.

Computations designed to show the actual effect on a specific flood cannot assume, as was done above, that the discharge remains constant. For the condition listed under (a) above it is found that the actual effect on the 1950 flood would be to raise the stage at Simmesport a few tenths of a foot while reducing the discharge down the Atchafalaya about 20,000 c.f.s. For the condition listed under (b) above, it is found that the actual effect in the event of a recurrence of the 1950 flood would be to raise the stage at Simmesport a little less than a foot, while reducing by about 40,000 c.f.s. the intake into the Atchafalaya River.

The above statements omit from consideration that if the backwater stages rose from natural causes over a long period of time, other and perhaps offsetting changes might occur simultaneously elsewhere. For instance, as in the cited comparison of the 1950 flood to the 1945 flood, upstream channel improvement might more than offset the rise of stage in the lower basin.

Present Discharge Capacity of the Atchafalaya River between Levees

At Mile 52.8, about two miles above the end of the East Atchafalaya River levee, the 1950 flood approached within a few tenths of the approved levee grade. In this vicinity, therefore, the capacity of the approved levee grade is not much greater than 620,000 c.f.s. The freeboard increases upstream from this point and 10 miles upstream, at Mile 42.9 just below Krotz Springs, it was 2.4 ft. In the five miles below Krotz Springs, computations show the approved grade will carry 730,000 c.f.s. without overtopping. Above Krotz Springs, flow line computations show that 750,000 c.f.s. may be carried without overtopping the levees. At Simmesport the computed stage for this discharge is 58.8 ft. m.s.l., one foot below the project flood stage. The 1950 rating curve extended does not check this computation too well; it shows 710,000 c.f.s. for the same Simmesport stage, or 730,000 c.f.s. for the project stage of 59.8 m.g.l. The computation is believed to be more reliable than the rating curve extension, and if the smaller figure, given by the rating curve, is used it should be regarded as a conservative estimate.

Carr Point Cutoff

Carr Point Cutoff, a cutoff from the Mississippi River to Old River shown on Plate B15, Appendix B, was authorized in 1944. Bank caving on the lower side of Old River in the vicinity of Phillipston, approximately 1/2 mile beyond the junction of Old River and the Mississippi River, was threatening the main line levee in that vicinity. Corrective measures to prevent a levee failure under the then existing conditions would have required a set-back levee about 2-1/2 miles long, or about 4,000 linear feet of revetment. The shortage of critical material at the time would not allow the revetment.

The site of the cutoff was approximately 1-1/4 miles upstream on the Mississippi River from the junction with Old River and approximately 1-1/2 miles downstream from the junction on Old River. The distance across the neck at that point was about 700 ft. at the time, with active caving on both sides. The difference in water surface elevation across the neck was about 1-1/2 ft. at stages around bankfull.

The indications were that a natural cutoff would occur within a few years, but probably not in time to avoid corrective measures to prevent a levee failure.

It was estimated that the increased slope in the Old and Upper Atchafalaya Rivers resulting from Carr Point Cutoff would increase the flow at Simmesport from 5,000 to 10,000 c.f.s., or approximately two percent of the bankfull flow. The tendency of the increase in flow in the Atchafalaya River is, of course, toward increasing the rate of enlargement. The actual effect of making the cutoff probably was to introduce the additional water two or three years before it would have been introduced by means of a natural cutoff. The effect of making the cutoff can be considered minor in the course of events which have led to the enlargement of the Atchafalaya.

Angle of Diversion

Some importance has been attached to the angle of diversion in former changes in the course of the Mississippi River. An acute angle to the direction of flow in the main channel has existed at all permanent diversions that can be traced (reference page A41, Appendix A).

It has been established that for an idealized condition; i.e., a straight channel with bed load moving along the bottom, the angle of diversion affects materially the diversion of bed load. It is said that for such a condition with the same bottom elevation, a 90 degree diversion might take as much as 90 percent of the bed load with 50 percent of the water. The theory is that the slower water along the bottom, which transports the bed load, would be diverted under such a condition.

There is also the fact that an acute angle of diversion would require less change in direction of flow and consequently less loss of energy at or in the vicinity of the point of diversion. This in turn would affect the energy available for the transportation of suspended load and bed load, or for scouring the channel, and might conceivably affect the diversion if the forces were near a balance. This again is a more or less idealized condition which probably could not exist for a long period.

Other factors such as gradient advantage, type of soil along the diversion route, degree of confinement, etc., are important also in connection with changes in the course of a river.

It appears that the angle of diversion would be an important factor only under special conditions such as might exist at crossings along the Mississippi River.

Old River takes off from the Mississippi on the concave side of a bend. Bed load in the river travels along the bar, or convex side of the bends. The conditions here are such that appreciable quantities of bed load are not likely to enter the diversion and consequently the angle of diversion probably is not of any appreciable significance in controlling the rate of increase in the channel.

The situation which exists at Old River is not without parallel on the Mississippi River. We might compare it with the cutoffs which have been made. At several of the cutoffs the angle has been approximately at 90 degrees with the direction of the current. They took off from the concave side of the bend, similar to the location of Old River. The main factors affecting their development were a gradient advantage and the fact that they were deep enough to take flow at all stages. The results were a rapid enlargement of the cutoff channel and a deterioration in the bendway channel.

EXTRACTS FROM
VARIOUS EARLY REPORTS
AND
MISSISSIPPI RIVER COMMISSION FILES

PREPARED IN

OFFICE OF THE PRESIDENT
MISSISSIPPI RIVER COMMISSION
CORPS OF ENGINEERS, U. S. ARMY

CONTENTS

EXTRACTS PERTAINING TO THE ATCHAFALAYA RIVER STUDY

Humphreys and Abbot Report upon the Physics and Hydraulics of the Mississippi River, 1861

Page 41:

"The bayou Tensas heads in lake Providence, and after being joined by a parallel stream, bayou Macon, which heads above Gaines' landing, and by many other swamp-land drains, becomes a river some 600 feet in width and 16,000 square feet in cross-section in the high-water season of the year. The gradual extension of the levee system upon the banks of the Mississippi has deprived this net-work of bayous of their chief supply of water, and they now never rise to the level of their banks except upon the occurrence of many large crevasses in the Mississippi levees. Formerly, the whole region was deeply inundated in floods. In 1828, when the greatest inundation of which there is even a tradition occurred, the average depth of the water across the swamp on the Louisiana boundary line was 7.1 feet; and between Vidalia and Harrisonburg, 7.7 feet. The mean depth throughout the whole swamp was probably as much as 7 feet. This inundation, however, was fully 3 feet deeper than any other of which we have records."

Page 69:

"The effects of these two cut-offs (referring to Red River and Raccourci) on flood have been widely discussed. Both Ellet's report and that of the Delta Survey discuss the cut-offs in some detail. Professor Caleb G. Forshey published a discussion of them in the Transactions, American Society of Civil Engineers, 1876. The conclusions of these early writers are based on fragmentary and inaccurate data, and can not be regarded as either authoritative or conclusive. Although the cut-offs were attended by local readjustments of the channel, there is no conclusive evidence that they themselves have appreciably affected flood heights. The enlargement of the Atchafalaya can not be considered the result of these cut-offs. As has been shown above, that enlargement was primarily the result of the destruction of the raft and the development of the Atchafalaya levees. Indeed, it is probable that Shreves Cut-off was an indirect benefit in the Atchafalaya problem. It interposed the inefficient Old River channel between the two rivers and trained the discharge of the Mississippi in such a direction that there has been no tendency on the part of that river to break through again into the Atchafalaya River channel. Had Shreves Cut-off not been made, it is possible that the removal of the Atchafalaya raft and the extension of the Atchafalaya levees would have been followed by a very serious diversion of Mississippi discharge."

Page 85:

Annual discharge of main Mississippi, 21,300,000,000,000 cu. ft.
Mean annual discharge, 675,000 cu. ft. per sec.

Page 127:

Yearly amount of rain in the basin of the Mississippi, 89,400,000,000,000 cu. ft.

Page 146:

Sediment for above discharge computed as 887,500,000,000 pounds or 1 mile square and 263 feet thick.

Page 171:

"In the western part of the Atchafalaya basin the flood (1828) was the greatest of which we have record, for, there being no levees for several miles below the mouth of Red River, and Shreve's cut-off not yet having been made, the water from the Tensas bottom poured over the banks in immense quantities. At the upper mouth of bayou Atchafalaya it was 2.0 feet above the ground and the flood level of 1850; at the mouth of bayou de Glaize it was 4.5 feet above the ground and the flood level of 1850; at the mouth of bayou Courtableau it was 4.0 feet above the ground and 3.0 feet above the flood level of 1850; at the head of Grand lake it was 4.3 feet above the flood level of 1850; and at Brashear City, 3.0 feet above the same level. The overflow extended to the extreme western limit of the alluvial formation, instead of only 6 or 8 miles from bayou Atchafalaya, as in ordinary floods. The Courtableau at Washita was at least 10 feet higher than in 1850. The plantations along the upper part of the Teche were not flooded, but the crops were lost on those within the influence of the back-water from the Atchafalaya overflow. At St. Martinsville the bayou was some 15 or 20 feet above low water, the usual range being only 3 or 4 feet.

"The eastern part of the Atchafalaya basin, indeed the whole region bordering upon the Mississippi below the head of this basin, seems to have nearly escaped damage; the only exception being the Grosse Tete region, which was deeply flooded by backwater from the Atchafalaya overflow, and by a break in the ground levee of the parish of Pointe Coupee near Morganza."

Page 174:

"The damage occasioned by this flood (1850) was immense. The St. Francis and Yazoo bottoms were not protected by levees, and were both deeply flooded. The Tensas bottom was submerged more effectually than in any year subsequent to 1828. This was in some degree due to the heavy rains already mentioned, which filled the swamp-drains before the crevasses occurred, and thus retarded the escape of the Mississippi water. The principal breaks were several above the Louisiana line, which flooded bayou Macon; that at Point Lookout, just below Lake Providence, which was 1.5 miles wide and from 5 to 8 feet deep; that near Island 102, which was 1 mile wide and 7 feet deep; that between Lake Providence and New Carthage (gap in levee), 10 miles wide and about 3 feet deep; that just below Rodney, which was 1300 feet wide; and that opposite Ellis cliffs, which was 3000 feet wide. These dimensions are only approximate, as no survey of the breaks was made. The history of the flood in this bottom is well exhibited by Mr. Mandeville's gauge-record (Appendix B), kept on bayou Tensas at the crossing of the Vidalia and Harrisonburg road. The water rose steadily until March 15, then declined slowly until early in April, then rose again until the middle of May, when it attained its highest point, and then rapidly subsided. The flood was 1.6 feet higher than in 1844, and 3.0 feet higher than in 1849 and 1858 at this locality. At Trinity (marks of Major Liddell) the water was 1.8 feet higher than in 1844; 3.0 feet higher than in 1849; and 3.8 feet lower than in 1828. At the mouth of Black river, this flood was 3.0 feet above that of 1844, and 5.0 feet below that of 1828. After these figures, it is needless to add that nearly the whole region was submerged and the crops destroyed.

"Below Red-river landing the country fared but little better. The water pouring from Red river exceeded the discharging capacity of bayou Atchafalaya, and the surplus forced its way into the Mississippi by both of the mouths of Old river. The flood from above, augmented by this new supply, maintained an elevation sufficient to keep the numerous crevasses below Red-river landing actively discharging for more than four months. As a detailed computation of the quantity of water thus taken from the river will be given in Chapter VI, the effects of the overflow alone will be referred to here. The Atchafalaya basin was more deeply flooded than in any other year since 1828. At Brashear City, the water began to rise rapidly on May 10, and continued to do so until June 20. It then stood at a level about 3 feet lower than the highest point attained in 1828 until July 4, when it began falling so rapidly that the land was uncovered in 4 days. The basin between bayou La Fourche and the Mississippi escaped nearly uninjured. The crops upon the left bank, above New Orleans, were much injured by the celebrated Bonnet Carre crevasse, which attained a width of nearly 7000 feet, and continued flowing for more than six months."

Page 176:

1850 Flood. "The water from Red River exceeded the discharging capacity of Bayou Atchafalaya and the surplus forced its way into the Mississippi River by both mouths of Old River. The Atchafalaya Basin was more deeply flooded than in any other year since 1828."

Page 352:

"In their former condition, these regions were always more or less flooded in the spring by Mississippi water which escaped into them through many bayous, both large ~~and small, and over the natural banks~~. ~~At present, levees to exclude this~~ water are under construction, and are already sufficiently advanced to modify materially the action of the swamps."

Page 364:

In nearly the whole flood period in 1858, there was no current in the mouth of Old River. During this time, the discharge of Red River into Old River was just sufficient to maintain the normal discharge of Bayou Atchafalaya. During the period May 2-August 3, 1858, it was estimated 120,000 c.f.s. was discharged down the Atchafalaya.

Page 368:

"The Tensas bottom was flooded (in 1828) to such an extent that, opposite Natchez, the water level in the swamp was nearly the same as in the river. Escaping in vast quantities at the southern border of this region, the water encountered a great flood in Red river. No natural channels existed for the discharge of such an immense accumulation. The result was an overflow of the entire southern bank of Red river from Alexandria to its mouth (excepting the Avoyelles prairie), and of the bank of the Mississippi from the mouth of Red river to the head of the levees, which then extended nearly up to Red-river landing. This great waste-weir saved the region bordering upon the Mississippi below the head of the levees from inundation, only one serious break—that near Morganza—occurring below that point."

Page 373:

"It is well known that the Red-river and Raccourci cut-offs are in close proximity to each other. The first was made in 1831, and shortened the river 18 miles; the second was made in 1848 and 1849, and shortened the river 21 miles. The flood of 1851 was as high as that of 1828 at points 100 miles above and below the mouth of Red River, and the accessions received from Red river were the same in each flood. It is concluded, therefore, that the river would have been as high at Routh's point in 1851 as in 1828 but for the cut-offs. The flood of 1851 was, however, 4.6 feet below that of 1828. This, then, is the effect of the two cut-offs in lowering the flood level just above their site."

Page 405:

To close Old River would, if executed, entail disastrous consequences. The Red River, at its mouth, in floods of its own drainage, is 225,000 c.f.s. The discharge of the Atchafalaya at bankfull is only 130,000 c.f.s. If, therefore, the entrance of Red River into the Mississippi should be closed, the Red River Valley, the settlements along Bayou des Glaises, and the Atchafalaya Basin would all be deeply inundated at the recurrence of every Red River flood.

Page 417:

"It may also be added that the enlargement of the bayous Atchafalaya and Plaquemine, since the construction of levees, is a well-established fact. This enlargement has contributed to depress the floods at New Orleans."

"Spillways in the Lower Mississippi River"—H. D. 95,
70th Congress, 1st Session, December 1927

This report called for surveys of the various sites with the view of estimating costs of controlled or regulated spillways between Point Breeze (above Old River) and Fort Jackson, La., to prevent waters of the Mississippi River exceeding stages of 16 to 20 ft. on the Carrollton gage, near New Orleans, La., and of 46 to 48 ft. at Simmesport, La., on the Atchafalaya Outlet. It was pointed out in this report that Old River and the Atchafalaya form, under present conditions, a vital relief outlet for floods of the Mississippi River. The levee terminates just below Point Breeze and begins again just below Old River. This gap, together with the channel section of Old River, permits floodwaters to enter the lowlands to the west known as the Tensas Basin. The levee systems of Old River, the Upper Atchafalaya and the Bayou des Glaises form, in effect, a long earth dam which converts the lower Tensas Basin into a reservoir into which the Upper Mississippi and the Red Rivers pool their floodwaters, and out of which the Lower Mississippi and the Atchafalaya take those waters to the sea. Also that New Orleans, with a population of about 100,000, is one of the great ports of the country and an important railroad center. The wharves which serve the port are built in a line about 10 miles long on the riverbank. The levee and wharves have been built to the new grade line about 25.2 ft. at Carrollton, and these wharves can serve ships without loss of efficiency when the river stages are not higher than 20 ft. on the Carrollton gage.

The Morganza project was outlined and, with the adopted minimum flood, the maximum discharge below the Morganza Spillway would be 1,700,000 c.f.s.

The Atchafalaya Floodway would have no control structures at the head of the floodway. Controlling gates would not be effective unless they extended across the Atchafalaya River itself, and the construction of a gate structure in the great depths found in the river would be a hazardous and extremely costly engineering feat. All railways and highways crossing the floodway, of sufficient importance to warrant their expense, should be raised with adequate openings to accommode floodwaters.

The Board did not consider it necessary to discuss the effect of the spillway system on the discharge capacity of the Mississippi River. The discharge of water through spillways, no matter where located, will cause indirect damage by interfering with drainage, the development of communication, and by allowing reclaimed areas to relapse to their original condition. Spillways afford, however, the safest method of passing a great flood through the delta below Old River.

Annual Report of the Chief of Engineers, 1882

Page 1396:

"Simmesport is the shipping point for the country up Bayou De Glaize as far as Evergreen. Both banks of the river here are caving, and three successive levees have been built on both sides of the river, and in some places the fourth levee is now at the top of the bank and in danger of going in. Mr. Barbre, who settled here in 1828, and several other old inhabitants, told Mr. Collins that formerly at low-water there used to be a good ford for stock at Simmesport; but now the river is 630 feet wide at low-water and about 50 feet deep, while during high-water of 1874 it was about 100 feet in depth. This is said by old inhabitants to be the same place where the ford was in 1840, and at that time a log was used by foot-passengers to walk across on, the ends of the log resting on either side of the river, which is said to have been but 40 feet in width."

Annual Reports of the Mississippi River Commission

A.R. 1880, page 2771 (Report by General Gillmore, Presdt. MRC, and Members Harrod and Suter):

"Junction of Mississippi, Red and Atchafalaya Rivers. . .

"Much attention is due to the consideration of affairs at Red River. Shreve's Cut-off, in 1831, severed from the Mississippi the bend in which Red River discharged, and from which the Atchafalaya was supplied. Prior to this the navigation of lower Red River was impaired by backwater from the Mississippi, which occasionally extended to Alexandria, on the Red, and to Monroe, on the Ouachita. The Atchafalaya was rafted heavily. After the cut-off, Red River sought the Mississippi by the shortest route, through upper Old River, north of Turnbull's Island; while lower Old River, from the head of the Atchafalaya to the Mississippi, silted up and bore a heavy willow growth. Until 1865 Bayou Plaquemine was open, and through it and the Atchafalaya was the navigable approach to the Attakapas, Opelousas, and Atchafalaya country. To maintain this route the State of Louisiana removed the raft obstructing the streams. To this work, and the disturbance of the equilibrium between the Mississippi, Red and Atchafalaya rivers by the cut-off, is due the enlargement of the latter stream.

"It will be observed that, for several years after the cut-off, the discharge of Red River passed to the north of Turnbull's Island. In 1873, after great enlargement of the Atchafalaya, Lower Old River, silted and grown up, cut out, and the northern channel closed, in which condition it now remains. Down the Atchafalaya had become the line of least resistance, and only the surplus discharge of Red River passed beyond its head along the south channel to the Mississippi.

"As the Atchafalaya continued to enlarge, its demands became more exacting, and this surplus was so reduced and uncertain that Lower Old River became a wide, shallow, slackwater basin, receiving sediment alternately from the Mississippi and Red rivers. In 1876 this process had nearly closed low-water connection; and the waterway near the lower end of Turnbull's Island was only about 100 feet wide and 20 inches deep, with a fall of about 2 feet in a quarter of a mile towards the Atchafalaya. By the end of the low-water season, this bar cut out. In 1877 a similar bar formed nearly a mile towards the Atchafalaya, the scoured channel of 1876 remaining open, with raised banks. This bar was dredged out by the State of Louisiana. Similar obstructions occurred in 1878, 1879, and 1880, reforming each year at points nearer the Atchafalaya, and the channels dredged in previous years remaining open."

A.R. 1881, page 130:

". . . Atchafalaya Rivers. . .

* * * *

"Darby, in his Geographical Description of Louisiana, states: 'The Atchafalaya was first obstructed by timber in 1778.' In Allicott's journal we find that 'this branch (the Chafalia), notwithstanding its magnitude, is not navigable to the Gulf of Mexico, owing to the immense floating bridge or raft across it, of many leagues in length, and so firm and compact in some places that horses and cattle are driven over on it. This surprising bridge or raft is constantly augmenting by the trees and rubbish which the Chafalia draws out of the Mississippi.'

"Major Stoddard took possession of Upper Louisiana in 1804, under the treaty of cession. He was stationed about five years on the Lower Mississippi, and six months on the Red River. He stated that 'the channel of the Chafalia, a few miles only from the head of it, is completely obstructed by logs and other material. Were it not for these obstructions, the probability is that the Mississippi would soon find a much nearer way to the Gulf than at present, particularly as it manifests a constant inclination to vary its course.'

"And again, 'This outlet (Chafalia), in leaving the Mississippi about 3 miles below Red River, is nearly 200 yards wide. In low-water it is about 18 feet, and in high-water about 30 feet in depth. Thirty miles from the Mississippi it is obstructed by a raft of wood, bound together by a heterogeneous mixture of ligneous and other matter. In the course of 20 miles the navigation is choked by ten or twelve similar rafts, and it is calculated that the aggregate obstruction occasioned by them is not less than 9 miles. Some of them form good bridges, and are passable at all seasons. Many of them are covered with willow trees, and a considerable portion of them are 10 inches in diameter. These rafts rise and fall with the water, and are therefore justly termed floating bridges. Below the rafts the Chafalia affords a beautiful sheet of water at least as far down as Cow Island, from 75 to 150 yards wide, and from 25 to 30 feet deep in the dry season. The current of the Chafalia is quite gentle, till it is joined by the Plaquemine, 160 miles from the outlet of the Mississippi, when its velocity is considerably increased.'

"Finally, Darby writes in 1817:

" 'On the subsiding of the spring floods, I have seen the water flowing from the Atchafalaya into the Mississippi. This circumstance is very contrary to the common opinion on the subject, but it is true. I was witness to the effect in the fall season of three years ago. Indeed, so completely is the communication cut off at low-water between the two rivers, that very often a common canoe cannot be taken from one to the other.' "

A.R. 1888, page 2298:

"Report of Captain Dan C. Kingman. . .

* * * *

"I have given to the 'Atchafalaya problem' much thought and study. I visited the locality eleven times during the past season and spent forty-seven days on the work.

"It is evident that there are four different and to some extent conflicting interests to be considered in any plan for the rectification of the Red and Atchafalaya rivers, namely:

1. The navigation of the Mississippi River.
2. The navigation of the Red River and its tributaries.
3. The navigation of the Atchafalaya and its connecting waters.
4. The interests of the inhabitants of the valleys of these several streams.

"Whatever is done, therefore, must have in view to maintain all times the free and unobstructed navigation of the Mississippi River at and near the mouth of the Red; must secure at all stages of the water a safe and easy entrance into the Red River and its tributaries; must effect a like result for the Atchafalaya and its connecting waters; and, finally, must secure all of these benefits without producing any change in the high-water regimen of these several rivers whereby territory shall be subjected to overflow which is now safe. And any plan which does not promise to secure all of these results is defective and ought to be rejected. The dangers to be averted and the obstacles to be overcome are, so far as the Mississippi River is concerned, the Angola Bar and the deflection of its waters in ever-increasing quantities down the Atchafalaya, which might in time (due to its shorter length) exceed in capacity the main stream, and finally become the sole outlet of the Mississippi. The first heavy storm would then close the present mouth of the river, the bar at Angola would soon rise above the water, and the city of New Orleans and all the towns and villages for more than three hundred miles from Red River to the jetties would be situated on an inland lake. Nor would this great loss be compensated in any measure by the small advantage of a good harbor at the new mouth. The Atchafalaya Bay is much less favorable for improvement than was the present mouth of the Mississippi."

A.R. 1888, page 2299:

"Report of Captain Dan C. Kingman. . .

* * * *

"It may perhaps be asked how there can be any danger of the Mississippi going down to the Atchafalaya if Old River is constantly filling up, or how the Atchafalaya can get larger and Old River smaller at the same time. The high-water width of Old River is equal to that of the Mississippi and very much greater than that of the Atchafalaya, so with less mean depth it can carry much more water than the Atchafalaya can. The work of the water is therefore applied to the smaller sections of the latter river many miles below its head. But when once the Atchafalaya is large enough the Mississippi will make very short work with the obstructions in Old River. As to the remedy, several have been proposed, the purpose and effect of which is shown upon the accompanying sketches."

A.R. 1891, page 3470:

"Paper by Captain Charles F. Powell. . .

* * * *

"*History.*—Before Shreve Cut-off, 1831, this stream was an outlet proper of the Mississippi; since the cut-off the Atchafalaya has remained practically an outlet, either by drawing off Red River water, which otherwise would have gone to the Mississippi, or by receiving water from the main river via Upper or Lower Old River, one or both. In the first case the Mississippi is depleted by the diversion of a tributary; in the other by the direct abstraction of part of its volume. In both cases effects in the same direction, on the bed of the main river below Old River, although perhaps not of equal extent, might reasonably be expected.

"The Atchafalaya was formerly choked and nearly filled for miles by immense rafts of timber; the removal of the rafts was undertaken in 1840 and the work steadily prosecuted until 1861. From reliable statements and observations it appears that upon removal of the rafts the Atchafalaya rapidly enlarged. The early commission reports and Maj. Benyaurd's reports about 1880 detail circumstances showing the enlargement and express opinions to the effect that the Atchafalaya had again become an important outlet of the Mississippi. In the former-named reports are given the following comparisons of a section at the head of the Atchafalaya:

Authority	Year	Section area sq. ft.	High water, width ft.	Maximum depth ft.	Increase ft.	Per cent of increase
Delta survey	1851	24,400	730	52	—	—
Delta survey	1859	28,700	830	63	4,300	.172
Major Howell	1874	39,160	891	114	14,160	.605
Major Benyaurd	1879	52,100	940	130	27,700	1.134

* * * *

"A study of the results in detail discloses the further facts that the first effect of enlargement is expended in scouring out very deep, wide holes at frequent intervals, and when the average bed reaches the dimensions required to carry the volume put upon it, these holes are gradually filled up and a bed more uniform in section is developed. After that stage has been reached further enlargement, if any, is confined mainly to increase in width, due to a slow disintegration of the upper banks. This enlargement is compensated to a considerable extent by a decrease in mean depth.

"Here we also have an illustration of the direct effect of levees on the bed of a stream of no mean proportion.

"The extension of the levee on the left bank of the Mississippi River from Bougere downstream, and the gradual filling up of upper and lower 'Old River' by deposits of sediment, both tend to reduce the flood volume contributed to the Atchafalaya by the Mississippi River.

"This, coupled with the more important fact of the stability of the river bed in the upper reach of the Atchafalaya for a distance of over 13 miles, as established in the foregoing discussion, warrants the conclusion that the danger of the Mississippi River abandoning its bed for the shorter route to the Gulf of Mexico by the way of the Atchafalaya is, to say the least, very remote, and need have no further serious consideration, unless some very radical, unlooked-for change should take place in the regimen of the larger stream."

A.R. 1895, pages 3639-41, 3643:

"In the river and harbor act of Congress of August 17, 1894, appears the following provision:

> " 'At the head of the Atchafalaya and the mouth of Red River, Louisiana, for the rectification thereof: Continuing improvement, seventy thousand dollars, of which two thousand five hundred dollars may be used in improving Bayou des Glaises, in the parish of Avoyelles, and the said Commission is directed to report to Congress in their next regular report their views on the advisability of effecting a separation between the Mississippi and Red rivers at the present junction thereof and maintaining navigation between the same through Bayou Plaquemine or by means of a canal.' "

"Under this provision it becomes the duty of the Commission to submit their views upon the question of the complete separation of the Mississippi and Red Rivers.

"A proper solution of the problem of river improvement presented by the peculiar features of the flow of the three rivers—the Mississippi, Red, and Atchafalaya—is one that has engaged the attention of many engineers, and has for years been a matter of serious study of the Commission. The features of the case, and various projects proposed for a proper treatment of the locality, have heretofore been presented and discussed in the published reports of the Commission. It is therefore not deemed necessary at this time to discuss them further than to restate some of the views of the Commission, and to present facts relating to changes that have taken place in the condition of the locality, and changes that may be looked for in the near future. The two main features of the problem to be constantly kept in view are the navigation of the rivers and the control and disposition of flood waters, and it is impossible to deal with the subject in any method that does not adequately provide for both.

"In its report of December 19, 1884, the Commission discussed various projects for the rectification of the Red and Atchafalaya rivers; among others, the project upon which they are now called upon to express their views, viz, the separation of the Red and Atchafalaya from the Mississippi. The following is an extract from that report:

> " 'The separation of the Red and Atchafalaya from the Mississippi River has been proposed by extending and connecting the levees on the right bank of the Mississippi, above and below Old River, with a dam across that channel. This

dam would have to be constructed with the same methods and materials as that previously discussed for the Atchafalaya. While it would not be of equal magnitude with that dam, either in length or height, or in the depth of water in which it must be built, the foundation would be in the loose deposit with which the bed of Old River is filled. The opening of the Plaquemine route, as previously described, would also form part of this plan. The discharge below Red River, on the basis of the flood of 1882, would be increased 355,000 cubic feet per second, or to 1,950,000, which would still require some elevation of levees below.

" 'The connection of the dam with the adjacent levees would be more expensive than in the previous plan. Estimates are submitted without recommendation.

Cost of dam.	$1,200,000
Connecting adjacent levees, 2,000,000 yards at 25 cents	500,000
Locks and improvement of Plaquemine, Grand, and Atchafalaya Rivers.	1,561,620
To make secure present levees below Red River, assumed, as before, at a mean raise of 2 feet in their grade	~~2,872,500~~
To provide for the increased discharge below Red River consequent upon the execution of this plan would require an additional raising of grade, which, assumed in this case at 1 foot mean raise, would require	1,927,500' "

* * * *

"It is not the opinion of the Commission that the diversion of the Red River into the Mississippi is of the importance to the maintenance and improvement of the main stream that would render expedient the expenditure and risk that would be incurred by the magnitude of the project and the precautionary work necessary on the lower levees. Any reasons in favor of this plan are valid only in connection with the navigation of the tributary.

"To some extent the repair of existing levees along the Tensas front, now in progress, will tend to reduce the strain upon the Atchafalaya, but to provide absolutely against any injury from the augmentation of floods in the main river below some increase in the height of the levees below Red River will be necessary in this or any of the projects hereinbefore discussed."

A.R. 1916, page 3472:

"Original condition.—Prior to 1831 the Red River entered the Mississippi and the Atchafalaya flowed out from the Mississippi near the apex of a long horseshoe-shaped bend. In 1831 the Shreve cut-off was made across the narrow part of the peninsula forming the interior of the horseshoe bend, and left the mouth of Red and head of the Atchafalaya in a lake with a precarious and uncertain connection with the Mississippi River. In the course of time the entrance to and channel through this lake, known as Old River, became greatly obstructed during low water by sand bars and shoals. In addition to this, the channel of the Atchafalaya, forced to carry all of Red River, augmented during floods in the Mississippi by water from the latter stream, commenced to enlarge with great rapidity, until there was an apprehension that the Mississippi would desert its present channel and flow to the Gulf of Mexico via the Atchafalaya.

"Previous projects.—The project adopted by act of June 18, 1878, provided for maintaining a navigable channel during low water between the Mississippi, Red, and Atchafalaya by dredging and washing the channel with tugboats and a sternwheel steamboat. The act of August 2, 1882, transferred the supervision of the work to the Mississippi River Commission. The modified project adopted in 1896-7 provided for the construction of six low relief dams across the Atchafalaya near Simmesport, La., to prevent the further enlargement of that stream; the construction of a dam across Old River between the mouth of Red and head of the Atchafalaya; the reopening of a channel to the Mississippi River by way of Upper Old River, and the maintenance of navigation during low water by dredging. In 1897 this project was modified to provide only for the maintenance of navigation by dredging, and for maintenance of the sill dams already built, Nos. 1 and 3. Prior to 1897 the dam across Old River had been destroyed, first by making a cut through it, and subsequently by the current of the river.

"Present project.—The present project, adopted in 1897 by the Mississippi River Commission, provides for the securing of low-water navigation between the Mississippi, Red, and Atchafalaya Rivers by dredging; the maintenance of sill dams Nos. 1 and 3 in the Atchafalaya; and to repair, care for, and improve the hydraulic dredge the *Ram* belonging to the work."

~~Prior Reports Made by the Mississippi River Commission with~~ Relation to the Atchafalaya River

Survey of 1880-1881

The first authentic survey of the Atchafalaya Outlet was made under the direction of Major G. W. Howell in 1880-81. This survey extended from Berwick Bay to the mouth of Red River, and in a discussion thereon printed in the annual report of the Chief of Engineers for 1882 Major Amos Stickney, Corps of Engineers, U. S. Army, reported the improvement so intimately connected with the Mississippi that no recommendations could be made until the Mississippi River Commission should act.

The Atchafalaya River and its relations with the Mississippi River were discussed at length in the report of the Mississippi River Commission dated November 25, 1881, and throughout the intervening years frequent surveys have been made (along Old River) between the two streams, and a record of the changes that have occurred has been kept. In order to prevent the possibility of the diversion of the Mississippi River through the Atchafalaya to the Gulf, two mattress sills were laid across the Atchafalaya in 1887-89, at a point about 4 miles below its head.

Survey of 1904-1905

In order to secure reliable data from which to deduce the extent and causes of changes that were in progress in the Atchafalaya River, a survey was made in December 1904 and January 1905 which covered the Atchafalaya River from Barbre Landing at the head, to the junction of Little Atchafalaya and Grand Rivers, a distance of 69 miles.

The survey of 1904-05 embraced taped lines, precise levels, and observations on Polaris at intervals of about 10 miles, for control; cross sections normal to the river bed at intervals of 100 meters, and topography by the transit and stadia method, including shore lines, locations of levees and sounding ranges, details sufficient to extend the sections at sounding ranges to the top of the banks, thence to the levees on both sides of the river, and details on the landside of the levees as far back as they could be located from the top of the levee.

Report on Changes in the Bed of the Atchafalaya

A discussion of the extent of the changes that occurred in the river bed during the interval of about 25 years between the surveys of 1880-81 and those of 1904-05, and the causes to which such changes were traced, is printed in the annual report of the Mississippi River Commission for 1906, pages 2478-81.

Surveys of 1910-11 and Report on the Separation of Red and Atchafalaya Rivers from the Mississippi

In compliance with the River and Harbor Act of June 25, 1910, requiring investigations as to the necessity, urgency, and practicability of permanently separating the waters of the Red and Atchafalaya Rivers from those of the Mississippi River, the following surveys and examinations were made during the period October 1910 to March 1911:

(a) A survey of the Mississippi River between the high-water banks for a distance of about five miles above the mouth of Old River and about five miles below the same. Cross sections were sounded normal to the stream at intervals of about 250 ft.

(b) A survey of Old River between the high-water banks from the Mississippi River to Turnbull Island, with cross sections at intervals of about 100 ft. The survey of Old River was extended to the head of the Atchafalaya with cross sections at intervals as nearly coincident with the sections of the New Orleans District survey as was practicable; the survey down the Atchafalaya was extended to Simmesport, with cross sections coincident with those of the 1904 Mississippi River Commission survey.

(c) A survey of the Mississippi River from near Union Point Landing (742 L) to near Black Hawk Landing (747 L). This survey covered Grand Cutoff Bayou and a section at Black Hawk Landing (755) between the Mississippi River and Red River, with a view to ascertaining the practicability of constructing a navigable waterway between the two rivers in this vicinity.

(d) A reconnaissance was made of the lower end of the Tensas Basin and such portions of the Atchafalaya Basin as was necessary for the purpose of determining approximately the extent of the overflowed area due to the floodwaters of the Mississippi River under conditions existing at that time.

A report on this examination, including detailed maps and hearings on the questions involved, and also extracts referring to consideration of the Atchafalaya problem from annual reports of the Commission as far back as 1881, was printed as House Document No. 841, Sixty-third Congress, 2d Session.

Separation of Red and Atchafalaya Rivers from Mississippi River

Sixty-third Congress, House of Representatives Document No. 841, Mississippi River Commission report dated November 21, 1913. Referred to Committee on Rivers and Harbors, March 19, 1914. Digest of report:

Separation of Mississippi from Red and Atchafalaya Rivers would require construction of a dam in Old River with certain levee connections, and the construction of a lock near Union Point, all at an estimated cost of $13,022,500.

If dredging in Old River was abandoned, the separation would be accomplished by deposits of sediments aided, above medium stage, with permeable dikes. Project is practicable, but not urgent; it will reduce expenses of developing lands for agriculture in the interior basins, but by adding burdens to those localities that are situated on the main (Mississippi) river. Interests threatened by proposed work are of greater importance than those to be benefited. The Commission indicated the separation would raise flood heights below Red River Landing (vicinity of Old River) about 4 ft. They also stated the increase would not be permanent.

Conclusions of Mississippi River Commission, Board of Engineers for Rivers and Harbors, and Chief of Engineers, U. S. Army:

That the permanent separation of the waters of the Red and Atchafalaya Rivers from those of the Mississippi River is not deemed advisable at this time.

Atchafalaya River, Louisiana, and Related Basins

Sixty-sixth Congress, House of Representatives Document No. 288, 1st Session, 1919.

Mississippi River Commission report to the Chief of Engineers, July 17, 1919, MRC file $\frac{2596}{EC}$.

Estimated cost of separating Red and Atchafalaya Rivers from Mississippi River	$13,022,500
Estimate on pages 15 and 16 of printed report as follows:	
Dam and connecting levee	1,500,000
Canal and lock	4,322,500
Enlarging levees	7,200,000
Total	$13,022,500
Estimated cost of protecting interior basins from floodwaters of Mississippi River by means of levee *without* the separation of Red and Atchafalaya Rivers from Mississippi River	$5,131,750
Estimated cost of protecting interior basins from floodwaters of Red River by means of levees with separation of Red and Atchafalaya Rivers from Mississippi River, completed	$3,751,200

* * * *

Conclusions of Mississippi River Commission: ". . . that the interests of navigation are not injuriously affected by the protection of the Atchafalaya outlet and its basins from floodwaters of the Mississippi River and that the separation of Red and Atchafalaya Rivers is not necessary thereto; that such protection can be carried out under Flood Control Act of March 1, 1917."

Report on Survey of Atchafalaya, Black, and Red Rivers in Louisiana

By Act of Congress approved March 3, 1921, the Mississippi River Commission was directed to make an examination and survey with a report to Congress of the Atchafalaya, Black, and Red Rivers in Louisiana, specifying a general plan with recommendations for the execution thereof that will give the greatest measure of protection to the basins of said rivers from the floodwaters of the Mississippi River, consistent with all other interests of the Lower Mississippi Valley.

Under date of July 6, 1921, the Mississippi River Commission directed its Secretary to make the necessary surveys to prepare plans for protection of the basins from Mississippi River floodwaters. Surveys were made and a field report with estimated cost rendered on July 18, 1922. This report was reviewed by Mississippi River Commission personnel and a report rendered to the Secretary, Mississippi River Commission, on August 15, 1922 (Mississippi River Commission file 2748/F.h.). All previous reports and the field report of July 18, 1922, were reviewed covering this area, including the Red and the Black Rivers, and references made to the printed publications containing these data. Each basin was described in detail, and estimates of cost furnished for proposed levees, drainage, sluiceways, and pumping plants to protect the lands in the basins north of Bayou des Glaises and Old River from the Mississippi River as follows:

Levees	$15,428,418
Interior drainage	1,674,900
Sluiceways	950,000
Pumping plant	6,434,000
Total	$24,487,318
Area in acres	830,200
Cost per acre	$29.49

Examination and Survey for the Protection of the Basins of the Atchafalaya, Black, and Red Rivers from the Flood Waters of the Mississippi River

Under Act of Congress approved March 3, 1921, surveys were made in 1921 and 1922 and a report submitted by the Mississippi River Commission to the Chief of Engineers under date of February 28, 1924. The report was returned by the Board of Engineers for Rivers and Harbors for rewriting to correct certain errors and elaborate on certain items. The revised report, dated July 1, 1926, was sent to the Chief of Engineers and various plans with estimates discussed as follows:

Protection without closure of Point Breeze Gap. Each basin is described in detail and the levees proposed conform to standard Mississippi River Commission levees with grade line 3 ft. above the highest known flood.

The estimated cost of the proposed levee protection was $15,503,218, which included cost of extending the Atchafalaya levees. About 315 miles of levee and a yardage of 51,281,260 were used as a basis for the estimate. This levee project will give the measure of protection desired and will not injuriously affect any interests in the Lower Mississippi Valley. ~~The Commission recommended the protection of~~ the basin by levees as shown above, to be carried into execution as Federal and local funds therefor become available.

In order to make the reclamation complete there would also be required, for pumping plant, drainage canals, sluice gates, and other main features of drainage for Cocodrie and Sabine Basins, $7,360,900, making a total of $22,864,118. This does not include lateral drainage.

Protection by closure of Point Breeze Gap. Another method of accomplishing the project is presented in the closing of the Point Breeze Gap in the Mississippi River levees coupled with smaller levees along the tributaries. This method has decided advantages in simplifying the drainage of the lands and reducing the ultimate cost, but the Mississippi River levees would have to be enlarged from Natchez downstream and vigorous opposition must be expected from interests along the lower river. The estimated cost of this method of protection is:

Levees from Point Breeze down to Atchafalaya levee	$1,150,000
Canal and lock at Old River	5,022,500
Interior levee protection from Red River floods	6,723,322
Enlargement of controlling levees below Natchez incident to closure	8,351,889
Total	$21,247,711
Deduct account, no further dredging at Old River	750,000
	$20,497,711

This estimate is $2,366,407 less than estimate for protection without closure of Point Breeze Gap, but it does not provide for additional bank protection or changes in water front terminals at New Orleans.

Various other means for lowering the flood levels of the Mississippi River submitted are:

Diverting the Mississippi River down the Atchafalaya. A definite and immediate result could be secured by turning the Mississippi River down the Atchafalaya which has about half the length and double the slope via New

Orleans. The diversion would obviate the necessity of further levee enlargement along the Mississippi River below the mouth of Old River and the city of New Orleans would be safe from damage by floods for many years, but it would be practically cut off from upriver navigation.

The cost of diverting the river, the construction of levees, bank revetment, and payment for land and property damages would be a prodigious sum.

It is generally believed that the sills placed across the Atchafalaya at Simmesport in 1888 have prevented the Mississippi River from taking the short cut down to the Gulf. If this be true, the removal of the sills would facilitate the diversion of the river at slight cost, and perhaps might be the only measure required to effect the diversion.

The estimated costs of damages incident to the diversion of the Mississippi River down the Atchafalaya were:

5 railway bridges at $5,000,000	$25,000,000
~~30,000 acres of land at $150~~	~~4,500,000~~
30,000 acres of swampland at $10	300,000
Improvements destroyed to Butte La Rose	500,000
Rebuilding Atchafalaya levees to Butte La Rose	7,851,000
Bank revetment, 50 miles at $300,000	15,000,000
Possible flood damage	10,000,000
Removal of sills	50,000
Total	$63,201,000

It should be borne in mind that a like diversion of the Mississippi River down the Atchafalaya by nature without the aid of man is not impossible. There are other items of expense in connection with this river diversion, but the figures given are ample, not only to show the magnitude of the problem, but also to show that the benefits accruing would not justify the cost.

Straightening the river to lower its flood levels. A favorite plan for lowering flood levels is by straightening the river, that is by cutoffs and elimination of bends. The lowering of the flood plane can be realized only by greatly increased velocities giving more rapid runoff and resulting in erosion of bed and banks. A systematic scheme of shortening the river by means of cutoffs would result in damage to lands and improvements, destroy levees, and require very large expenditures for bank revetment in order to hold the advantage gained. The cost would be very great, far beyond any possible benefits.

Increasing the floodway below Red River. From data presented in the report, a comparison of average cross-section elements shows definitely that from Red River down, the bed of the river has been practically stable for more than a quarter of a century. An estimate was made for increasing the width of the floodway some 2,000 ft. by moving the levees back 1,000 ft. on each side of the river below Red River to provide for additional flood volume.

The value of land and improvements thereon, such as houses, railroads, etc., exclusive of the larger cities, such as New Orleans, Donaldsonville, Plaquemine, etc., that would be sacrificed for such a floodway was $27,475,000. To replace the levees would be an additional $26,275,000. The total cost of the additional floodway would be $53,750,000, a sum so great, without including 26 miles of cities and towns, that it practically excludes its consideration.

Lowering the flood level of the Lower Mississippi River by means of reservoirs. Lowering of flood levels of the Mississippi River, especially below Red River, is a matter demanding the fullest possible consideration. The Commission has given much study to relief by reservoirs, and has always been forced to the conclusion that reservoirs offer no practical solution and that the lowering of the flood heights of the Lower Mississippi River by means of reservoirs is impracticable. A reservoir large enough to prevent overflow should have a capacity sufficient to retain all the water in excess of the bankfull flow, to be emptied as the flood recedes, at such a rate as will not cause overflow. It has been estimated that the flood of 1912 would have required a reservoir near the mouth of the Ohio with an area of 7,000 square miles and 15 ft. in depth.

New Orleans, an interested party. The interests of the city of New Orleans have never been lost sight of by the Mississippi River Commission in this great problem of flood control. Whatever steps may be taken to ameliorate the flood conditions in the basins of the Red and Atchafalaya, it is fully realized that the city of New Orleans must have special recognition commensurate with its large population and property values. Substantial provisions must be made for its safety by means of levees or other adequate practicable means as will eliminate all danger of disaster from floods.

The Commission in its annual reports up to 1934 stated that the Examination and Survey Report called for by Act of March 3, 1921, was being held by the Board of Engineers for Rivers and Harbors for the purpose of securing additional information and for further study. No further action has ever been indicated to date, as far as the Commission records show.

Special Report of the Mississippi River Commission on Revision of Plans for Improvement of Navigation and Flood Control of the Mississippi River, Committee Doc. No. 1, 70th Congress, 1st Session, pages 59 and 60, paragraphs 262 through 269:

It has been estimated that if the flood of 1927 had been confined between levees, the discharge past the latitude of Old River during the peak of the flood would have been 2,336,000 second-feet. While the 1927 flood was the largest of record, the Commission has elsewhere in this report assumed as a maximum probable flood one that would produce a flow past the latitude of Old River of 2,650,000 second-feet.

To carry such a flood to the Gulf between levee lines would require not only a material enlargement of the levees but, as an incident to such enlargement, a relocation of a large part of the levee line.

The estimated cost of protecting the delta below Old River against the assumed maximum probable flood, by means of levees alone, is $128,000,000. This estimate is based upon the proposed new levee section and an assumed freeboard of 5 ft., but does not include the cost of new rights of way. Were the latter included it would increase the estimate about $20,000,000.

It does not include the cost of raising the levees and wharves along the river front of the city of New Orleans, estimated at $33,000,000, nor does it include the cost of providing for Morgan City and the territory adjacent to Grand Lake, protection equivalent to that which will be provided under the alternative plan hereafter considered.

Except by greatly increasing levee heights, the flood-discharge capacity of the Mississippi River past New Orleans cannot be increased, at reasonable expense, beyond 1,400,000 second-feet, the amount discharged during the flood of 1927 with a spillway below New Orleans in operation.

Two alternatives to levees alone have been suggested for the control of flood-waters in excess of the present combined capacity of the main river and the Atchafalaya Outlet, and both have received careful consideration. One is a radical enlargement of the Atchafalaya Outlet secured by setting back the existing levees on one or both banks so as to provide a floodway of large discharge capacity, and the other the construction of a series of controlled spillways on the main river.

The discharge capacity of an Atchafalaya floodway will apparently be limited by conditions at Morgan City to 900,000 to 1,000,000 second-feet, such a discharge corresponding to a reading of 13 ft. on the Morgan City gage.

As this floodway alone would not suffice to carry off the excess waters of the assumed flood, it would have to be supplemented as an alternative to levees alone by a spillway on the main river above New Orleans with a capacity of about 250,000 second-feet, and a spillway below New Orleans of capacity to insure a discharge past that city of 1,400,000 second-feet, without increasing the Carrollton gage above 20 ft.

Of the spillway sites suggested, one at Bonnet Carre above New Orleans and ~~one at Caernarvon below New Orleans appear to be the most promising~~.

After due consideration of the data available, the Commission is of the opinion that the best method of providing for a flood flow of 2,650,000 second-feet below Old River lies in the creation of a floodway down the Atchafalaya River, to carry about 900,000 to 1,000,000 second-feet, the construction of two controlled spillways on the main river, each to carry about 250,000 second-feet, one above New Orleans discharging into Lake Pontchartrain and one below New Orleans discharging into Breton Sound, an enlargement of the levees along the Mississippi River below Old River, and an enlargement of the levees across the head of the Atchafalaya Basin.

The estimated cost of such plan including rights of way and other damages is as follows:

Atchafalaya Floodway.	$48,000,000
Atchafalaya revetment	4,500,000
Bonnet Carre Spillway	11,500,000
Caernarvon Spillway	10,000,000
Main river levees	53,500,000
Total	$127,500,000

Report on Red River Backwater Protection, Closure of Old River in Louisiana, 30 September 1943, Library File A-7-1928-43, 891:

Basis for project document—1st ind., 1 Feb. 1941, to letter dated 17 Jan. 1941, Tensas-Cocodrie Area (MRC 3356/188/254).

Plan submitted, with estimated cost:

Dam.	$1,700,000
Lock	8,500,000
Levees	1,285,000
Rights of way	15,000
Total	$11,500,000

The plan will give protection to an area of 1,200,000 acres at an average cost of $9.60 per acre for 16 out of 17 years. The contemplated improvements will not jeopardize the main Mississippi River levees and will satisfy the desires of local interests. Recommended that the plan outlined in the report at estimated cost of $11,500,000 be substituted for the authorized levees and improvements for the protection of the Tensas-Cocodrie area provided local interests (1) maintain the levee and dam, (2) will not raise the levees above limiting elevations established by Chief of Engineers, and (3) will save and hold the United States from any and all damages.

In the appendix, various methods of operation procedure to be used at Bonnet Carre, Morganza Floodway, and Old River are discussed with relation to the design of the Old River structures. The plan that appeared most logical was:

Morganza operating at bank level 54.8 ft. m.s.l. at Old River, resulting in diversion every 1.8 years.

Bonnet Carre operating once in every six years. This would represent an elevation of 56.0 ft. m.s.l. at Old River with flow of 1,700,000 c.f.s. below Old River of which Morganza would take 400,000 c.f.s., leaving 1,300,000 c.f.s. to pass New Orleans.

Lock, in Old River, 56 ft. x 550 ft., with 12-ft. depth over sill at low water. Sill elevation about -9 ft. m.s.l. Top elevation at 66 ft. (2 ft. above project levee grade), maximum height of structure 75 ft. above the sill. Highest probable lift about 55 ft. with fuseplug crevasses in effect. Two sets of miter gates would be necessary, one set to take care of reverse head conditions.

Dam would be hydraulic fill with 200-ft. crown at elevation 50 ft. m.s.l. with 1:20 side slopes. Dam to be topped with a standard "B" section levee to project grade.

Fuseplug to be about 1-1/4 miles long, built of sand with riverside clay blanket. This section would erode to bank level very quickly.

Roads would be placed on levees and the lock would be flanked by levees built to project grade.

Report on Red River Backwater Protection, Closure of Old River in Louisiana, April 1948, Library File A-9-1948, 1619:

Report to Chief of Engineers, 9 April 1948—returned 15 April 1948 approved by Gen. R. A. Wheeler, Chief of Engineers, under provisions of Act 15 May 1928, as amended, if and when the present authorization is increased by Congress from $14,000,000 to $29,000,000.

On 15 August 1950, Chief of Engineers, Gen. Lewis A. Pick, wrote the President, Mississippi River Commission, that:

"1. Inasmuch as the Act approved 17 May 1950 does not specifically authorize the closure of Old River, the 'Closure of Old River Report' submitted by letter of 9 April 1948 is not approved.

"2. The 1st ind. dated 15 April 1948 on the letter submitting said report is revoked."

A digest, in very general terms, is as follows:

Authorization. The Flood Control Act of 18 August 1941, which authorized the Tensas-Cocodrie levee, provided that the Chief of Engineers may in his discretion substitute other levees and appurtenant work for the protection of the Tensas-Cocodrie area previously authorized at a cost of $14,000,000. Some thought was given to substituting the closure of Old River for the Tensas-Cocodrie levee and appurtenant works if such plan proved a better solution. The construction cost index, 258 in 1941, was 432 in December 1947; therefore, the $14,000,000 authorized would result in cost of $23,000,000 under the later cost index.

Project document. Report of Mississippi River Commission dated 7 March 1941 and contained in H.D. 359, 77th Congress, 1st Session.

Previous reports. H.D. 378, 74th Congress, 2d Session, unpublished report dated 15 August 1940, "Flood Protection of Red River Backwater Area." (MRC 3356/188/25f.) Recommendation unfavorable.

Supplementary report dated 22 October 1940 on Tensas-Cocodrie Area, 1st Ind. dated 1 February 1941 to letter dated 17 January 1941 (MRC 3356/188/25x).

Two reports on Red River backwater protection by closure of Old River have been published as H.R. 841, 63rd Congress, 2d Session (1913 report) and H.R. 288, 66th Congress, 1st Session (1919 report), and a third, not published, was prepared in 1926. Each of these reports was for complete protection and found the closure plan to have merit, but did not recommend it. The principal objection lay in the difficulty and danger of attempting to retain the floodwaters of the Mississippi River without the use of the Atchafalaya River as an auxiliary outlet.

A report was prepared in 1943 considering the protection of the backwater area by levees, a lock, a dam, and a fuseplug to permit release of Mississippi River floodwater into the area once in 17 years. This plan was based on Morganza operating at bank level. The report found the plan to have merit but, probably due to the foreseeable difficulties of bank level operation of Morganza and fuseplug release into the backwater area, the report was never published.

A memorandum report, prepared in 1945, considered protection of the backwater area by a structure in Old River completely to control flow from the Mississippi River. The cost of the structure was found to be excessive.

Proposed plan. The plan consists of the extension of the existing levee from its present terminus below Point Breeze, across Old River to a connection with the adopted project levee on its south bank, the closure of Old River by an earth dam, the construction of a controlled inlet structure, the construction of a lock to provide for navigation, and the construction of a low levee called "Modified Tensas-Cocodrie Levee" to inclose part of the Tensas-Cocodrie area.

The controlled inlet structure is planned to consist of a section of Bonnet Carre-type weir, providing 3,864 ft. of clear opening with weir crest elevation at 52 ft. m.g.l., and an adjoining section of gated structure providing 420 ft. of clear opening with sill elevation at 30 ft. m.g.l. The openings will permit a discharge of about 800,000 c.f.s. when the Mississippi River is at project flood stage (about 65.4 ft. m.g.l. riverside of structure) and the backwater is about the stage requiring the opening of the West Floodway (about 63 ft. m.g.l. behind the structure). This provides some excess capacity. The 420-ft. section at elevation 30 ft. m.g.l. will provide a capacity of about 240,000 c.f.s. when the backwater stage is 47 ft. m.g.l. and the riverside stage is 58 ft. m.g.l., corresponding to the critical discharge of 1,250,000 c.f.s. passing Angola.

The control structure provides for release into the backwater during floods, also supplements low-water periods in order to provide for navigation a lock 75 ft. wide with sill elevation at minus 10 m.g.l., will pass about 16,000 c.f.s. at mean low water in Mississippi River (present conditions about 20,000 c.f.s.).

A modified Tensas-Cocodrie levee is included in the Closure Plan. The estimated cost of the plan is $29,000,000.

Right of way	$30,000
Spillway (needle type)	6,250,000
Spillway (gated type)	2,470,000
Channel dredging (gated structure)	600,000
Navigation lock	9,500,000
Bearing piles for lock	335,000
Channel dredging for lock	550,000
Levee enlargement below Shaw	560,000
New levee and Old River closure	1,550,000
Residences and service building	70,000
Degrading levee in spillway section	75,000
	21,990,000
Modified Tensas-Cocodrie levee	1,500,000
Engineering and overhead	5,510,000
Total	$29,000,000

The value of the Closure Plan in preventing capture of Mississippi River by the Atchafalaya River is also discussed. Commencing with the removal of the "raft" in 1861, the Atchafalaya River began to enlarge. The levees undoubtedly contributed greatly to the rate of river enlargement. Also, two sill dams were placed in the river at Simmesport with the view to preventing channel enlargement. Maintenance of the old sills ceased in 1926 by the United States. Capture of the Mississippi River would probably be prevented, whatever the cost, since New Orleans water supply would experience serious difficulties; navigation would suffer, new bridges and flood control measures would be required in the Atchafalaya Basin and near Morgan City. The present levees would become entirely inadequate. If the enlargement of the Atchafalaya River were to be opposed by the employment of sills, three were proposed at a cost of $5,000,000. The comparison of Old River Closure Plan with Tensas-Cocodrie Levee Plan and also with Tensas-Cocodrie and Saline Levee Plans are also discussed.

Conclusions. The Tensas-Cocodrie levee project will cost $9,000,000 and the Saline $7,000,000. Authority already exists for the expenditure of $14,000,000 in the Red River backwater area, and will probably be constructed at $16,000,000. Some device will have to be installed for retarding the enlargement of the Atchafalaya River before such enlargement extends through Old River to the Mississippi. At least $5,000,000 more might be expended within a few years for check dams or sills of some sort to arrest the enlargement process. This would make an eventual expenditure of $21,000,000.

Recommendations. That the existing project for flood protection of the Tensas-Cocodrie area be modified so as to afford protection to a larger portion of Red River backwater area at an estimated cost of $29,000,000, substantially as outlined in this report, subject to certain specified conditions provided by law.

The report and plan were recommended by the President, Mississippi River Commission, 9 April 1948, and the plan was approved by the Chief of Engineers, R. A. Wheeler, Lt. Gen., if and when the present authorization is increased by the Congress from $14,000,000 to $29,000,000. However, on 15 August 1950, Chief of Engineers, Lewis A. Pick, Major General, advised the President, Mississippi River Commission, that:

"Inasmuch as the Act approved 17 May 1950 does not specifically authorize the Closure of Old River, the 'Closure of Old River Report' submitted by letter of 9 April 1948 is not approved.

"The 1st Ind. dated 15 April 1948 on the letter submitting said report is revoked."

Unpublished Data Contained in Letters and Memoranda in the Files of the Mississippi River Commission and Lower Mississippi Valley Division

M.R.C. file 2314 Ff

Atchafalaya raft as affecting floods on the Lower Mississippi River. The first effectual effort toward removing the great obstructing raft in the Atchafalaya was made by citizens who resided on its banks in the fall of 1839. The raft had been, for a number of years, on the increase by the annual contributions of the Red, Ouachita, Black, and Mississippi Rivers.

Constant appeals to the State for aid, without success, induced a few citizens of the Atchafalaya, under the direction of Captain Laird, to take the remedy in their own hands, and availing themselves of one of the seasons of greatest drought, they went down to the raft in skiffs and set fire to it. The fire swept over the raft, thirty miles in extent, destroying thousands of alligators and burning off the immense mass of timber thirty miles in length and probably one hundred feet in height, to the water's edge. The water in 1839 was so low at the mouth of the Atchafalaya that foot passengers, by means of a plank about 15 ft. long, could walk across it. Soon thereafter, as the water rose, Captain Mayo was placed in charge of State boats and found no difficulty in securing a passage through the raft for steamboats. As soon as the raft was removed the river commenced widening and deepening. The State of Louisiana then took up the work, using snagboats, but the great Atchafalaya raft was not removed until 1842, and the first steamboat to pass through the Atchafalaya into the Mississippi River was the *Panola* on April 20, 1842.

The removal of the raft was not permanent, however, as the State Engineer reported in 1847 that the Atchafalaya was filled with raft and floating drift from two miles above Bayou Pigeon to within seven miles of its head. These rafts were broken up from year to year and evidently were all removed before 1855. In March 1860, the State Engineer stated that the high water of 1828 was referred to as having been unparalleled in lower Louisiana; that at that time the Atchafalaya was completely rafted and therefore carried off, as an *outlet*, but little water.

From records of 1852, C. G. Forshey notes that: In the years 1811, 1813, ~~1815 and 1823, the river height was about as great as in 1828 or 1844.~~ But the interests involved were not so great prior to 1828, and therefore less injury was sustained. In 1811 the devastation was so great north of Red River and on Point Coupee and elsewhere that many inhabitants, who had been encouraged by the long intervals since overflow to open plantations on the alluvial lands, abandoned their homes, having lost their stock and their crops.

MRC Library Research and Technical Records, paper 1456. In a paper written by Col. Chas. L. Potter, President, Mississippi River Commission, April 30, 1921, subject: "Is the Bar at Red River Landing Rising?" he stated:

"There is little hope that the effect of closing Old River (forcing additional water into the Red River Landing section) will cause a deepening of that section. Facts indicate that such forcing will result in added width, or added flood height, or both."

In paper by Col. Chas. L. Potter, President, Mississippi River Commission, June 1, 1922, subject: "Separation of Red and Atchafalaya Rivers from the Mississippi," he states:

"It may be conceded that, if the levees were high enough to take care of the increased gage heights that may be brought about by closure of Old River; and if they were far enough back to allow for the widening which may result from closure, the river would in time assume such a shape that greatly increased gage heights (above those now obtaining) would not occur. But meantime it is doubtful whether either condition obtains to an extent which would justify taking the chances. Changes in the lower river cannot, as Colonel Townsend says, take place until added gage heights have accomplished the work. General Gilmore shows the danger of a possible series of low flood years (accomplishing little toward assimilation) followed by a great flood poured into the unprepared river below. Both view the possible disasters to the lower river due directly to increased gage heights. If these, as claimed, will eventually be reduced, the reduction must be accompanied by increased depth, increased width, or a combination of the two. With the levees so close to the river banks throughout much of the lower river, there seems little doubt that extensive additional bank revetment will be required and that loss of existing levee lines will result. Can either increased gage heights, or widening of the river, be viewed without apprehension?"

Report on Cross Section Elements, Atchafalaya River, 1927 Survey Compared with Previous Surveys. Old File 2946 Ei. Library File Cross Secs 1172. In a previous comparison of elements derived from the 1904 survey, all reaches when compared with 1916-17 showed increases in area and width at low water and at bankfull stages. The maximum changes at that time were in reaches E and F where the area increased 200.0 percent at low water in E and 78.6 percent at low water in F.

The levee ends in reach E and the water, confined between certain limits, is scouring out a channel suitable to the discharge now flowing down the Atchafalaya. This scouring effect is also carried down into reach F but in reach G, where the water can spread over the surrounding territory, the channel area has not been so materially increased and the river is more in the nature of a large bayou with fairly stable banks.

If the levees are extended downstream and the water confined as in the upper reaches, the areas in reach G will also be increased due to higher velocities and added volume of water that this reach will be required to carry.

A comparison with 1916-17 survey shows the excessive scour and enlargement of section has extended downstream about 9 miles (from Mile 46 to 55 below the head but where the water is permitted to spread freely over the surrounding territory as in reach G), the old section about 11,300 sq. ft. in area is still in existence and shows practically no change. The lower end of the excessive change in section is now 55 miles below the head of the river and about 91 miles above its mouth near Berwick Bay via the long route around Grand River or about 68 miles via the short route through Grand Lake.

Letter from Dr. H. N. Fisk, 9 July 1945:

Subject: Geological Aspects of Increased Atchafalaya River Flow

Brig. Gen. M. C. Tyler, President
Mississippi River Commission
P. O. Box 80
Vicksburg, Mississippi

Dear General Tyler:

The following statements are in reply to your request for an opinion as to whether, from the viewpoint of the geologist, the continuing increase in flow of the Atchafalaya River is an indication that capture of the Mississippi River by the Atchafalaya is a possibility.

Opinion: There is a definite possibility that the Mississippi River will be captured by the Atchafalaya River. This opinion is based upon a study of the geological history of the several diversions of the Mississippi River which have occurred in Recent geological time and upon a study of the development of the Atchafalaya River. There is no way for the writer to predict when capture would take place without more facts on channel characteristics and data concerning development than he has at his disposal.

Nature of Mississippi River diversions: Several diversions of the Mississippi River have occurred during Recent geological time. Of these, the diversion of the river from its Bayou Lafourche course was the most recent and stages in the development of the present river course south of Donaldsonville are readily interpretable. Another important diversion occurred at an earlier date west of Vicksburg and resulted in the abandonment of the Walnut Bayou course of the Mississippi in favor of the present course between Vicksburg and Angola. Traces of accretion in both the Lafourche and Walnut Bayou meander belts clearly show the effect of a decrease in flow and give evidence of the history of development of the diversion which caused the abandonment of these once active courses of the river.

From the geological viewpoint, the history of a river diversion consists of two stages. The first stage covers a long period of time during which a channel is established through continued diversion of high-water flow. The second stage starts with the diversion of low-water flow into the new channel and covers a short period of time during which the entire low-water flow becomes concentrated in the new channel and the old channel becomes plugged with silt and sand.

Each diversion of the river reached completion because a gradient advantage was offered and because there was long continued flow through the point of bifurcation. The speed of each diversion apparently was determined by the nature of bed and bank sediments. Tenacious silts and silty clays hinder the scouring action which widens and deepens the new channel.

Judging from the history of the river below Donaldsonville, the point of river bifurcation from the Lafourche course, the new channel was extended seaward by the progradation of a distributary system. In the initial stage of diversion, scouring was limited to the point of "crevassing." Sediments derived from scouring overloaded the stream and forced it to deposit its load and to divide into several distributaries where its gradient was checked at the level of the adjacent lowland. High-water occupation of the "crevasse" channel resulted in gradual lengthening of the course along selected distributary channels. This process continued and the zone of steep gradients was gradually flattened and forced seaward until, with permanent establishment of the river, it reached its present position below New Orleans.

The lowering of slope which accompanied the seaward extension of the channel was accompanied by a progressive downstream deepening and widening of the channel. Deepening of the channel was in part brought about by the construction of natural levees which had a tendency to confine the increasing flow of water and thus promoted scouring. Complete low-water diversion was reached only after the river had developed a better channel than had been previously occupied by the river in its Lafourche course.

The development of the present channel below Donaldsonville is clearly shown in the presence of many minor abandoned distributaries above New Orleans. These apparently mark the progradation of the delta of the river as the final channel was developed. Many of these have been subsequently occupied by crevasses; others are seen only in the drainage lines. Once the main channel was established, however, its position changed very little. This lack of shifting is attributed to the thick sequence of clays and silts through which the channel scours. It is probable that because of fine-grained bed deposits the diversion at Donaldsonville was very slow as compared to upstream diversions where the new channel could be developed in sandy deposits.

After the main low-water flow has been established in the diversion position, abandonment of the old channel takes place very quickly. The texture of the accretion patterns in both Bayou Lafourche and Walnut Bayou clearly shows that silting of the old main channels was a rapid process. The first decrease in flow is marked by a cessation of normal meander growth and by the development of a few abnormally small bends and large bars for a short distance downstream from the point of diversion. Deterioration of the course progresses by growth of bars and filling of the channel, and it is marked by a pronounced straightening of the channel. The final flow is small and apparently continues over a long period during which the straightened stream migrates but slightly.

Atchafalaya River history: Records show that the Atchafalaya River was a distributary of the Mississippi River at the time of the earliest exploration of the region. Geological studies show that it was formed at a time, just prior to earliest explorations, when Turnbull Bend of the Mississippi intersected an abandoned course of the Red River. (Remnants of this Old Red River course are now followed by Bayou Des Glaises and Bayou Lettsworth.) At the time of the above intersection, the Red River was following its present course and was entering the upstream arm of Turnbull Bend. Study of the floodplain in the vicinity of the Atchafalaya River shows that the history of the development of the Atchafalaya was very similar to that of the early stages of the Mississippi River diversion channel south of Donaldsonville. Its history is dissimilar only in respect to a slackening in speed of development when the channel became choked with a raft shortly after the trunk stream had formed.

The old channel when intersected by the river provided an ideal low area in which a crevasse could form and be greatly extended. Waters released from the Mississippi reversed the direction of flow in the Bayou Des Glaises stream as far from Turnbull Bend as Simmesport where they broke out of the ancient Red River channel and spilled into the Atchafalaya Basin. The Atchafalaya developed slowly by forming distributary systems and by lengthening its course along favored distributaries. Many of the old courses branch from the present channel and can be traced into the surrounding marshes. Their position may have been determined by ancient river channels because most show a marked curvature not noted on other distributary channels.

Distributary growth is continuing and the silting of the upper end of Grand Lake is a well known fact. Slightly older distributaries which were being enlarged and lengthened within the last century are the well-defined Grand River, Bayou La Rose, Lake Mongoulois, Bayou La Rompe and other systems at the upper end of the Grand Lake lowland. These have more of the aspect of a true delta system than do those farther upstream. Their channels were better developed and capable of distributing a large volume of flow from the main stream.

Man's earliest record shows that after its initial development the Atchafalaya's growth was very slow until 1861 because it was choked with the Atchafalaya River raft debris. Until 1831, when Shreve's Cutoff isolated Turnbull Bend, the Atchafalaya head was favorably located for rapid growth and it is therefore probable that the slow rate of downstream enlargement of the channel was directly related to channel choking effect of the raft. Since 1861 when removal of the raft was finished river flow has increased steadily although a direct connection with the Mississippi is lacking. Undoubtedly, enlargement of the channel has been favored by the year round flow of the Red River.

When compared with stages in the development of the Mississippi River diversion channels, the Atchafalaya appears to be still in the early, long-continued stage of development during which the channel is lengthened and the slopes lowered. However, enlargement of the channel should be a much more rapid process in this latitude than below Donaldsonville where the top stratum is much thicker. Furthermore, engineering works along the river have speeded up the enlargement process. Flood controls have raised the high stage of the Mississippi and Red Rivers and have also raised the backwater level in the Tensas Basin. As a result, the Atchafalaya is provided with a much larger volume of water than would naturally follow its course. Artificial levees along the upper part of the river confine the increased flow and are responsible for a deeper scouring action than would be expected to occur under natural conditions.

There is to the writer's knowledge no deterioration of the Mississippi River channel below the mouth of Old River and therefore no indication of imminent danger of diversion of a large percentage of low-water flow of the river into the Atchafalaya. However, the rapid increase in the quantity of water carried by the Atchafalaya within the past few years is an indication that channel enlargement has been progressing at an increasingly rapid rate and that it may be expected to continue at an even faster one. Should such prove to be the case, scouring of the channel would be expected to occur upstream in Lower Old River and eventually to cause the capture of the Mississippi.

Very truly yours,

H. N. FISK
Consultant

Memorandum for General Tyler from Lt. Col. Lindner, 16 July 1945:

SUBJECT: Supplement to Memorandum entitled "Frequency of Flooding of Red River Backwater Area with Control Structure at Old River."

Flooding from headwater floods. In the basic memorandum it was shown that the maximum flows of record from the Red and Ouachita Rivers could not cause a stage in excess of 38 ft. (bankfull stage) at Simmesport which corresponded to approximately 46 ft. m.g.l. at Barbre Landing. The frequency of these flows was indicated as about once in 100 years. Further, it was stated that when and if the channels of the Red and Black Rivers deteriorated, levees would be needed to protect against headwater flooding. All this may be somewhat misleading in that it might convey the idea that flooding from headwater floods could not occur with present channel conditions. This, of course, is not true. Stages and discharges in the 1942 flood give a good idea of stages to be reasonably expected as a result of headwater flow. On 14 May of that year, 211,000 c.f.s. was measured in the Red River just below its junction with the Black. On that day the stage at Simmesport was 29.6 ft. on the gage and the stage at Barbre Landing was 36.4 ft. m.g.l. On the same day the stage at Acme was 47.7 ft. m.g.l., although it had been 0.7 ft. higher about one week earlier when Barbre Landing stage had been about 6 ft. higher. On 14 May the stage at Jonesville was 50.4 ft. m.g.l. The flow in the Black River at this time was 71,000 c.f.s. at Acme and about 50,000 c.f.s. at Jonesville.

Although the 1942 high-water period in the backwater area appears to be a rather protracted one, its length was caused in part by the Mississippi River which attained a stage of about 45 ft. m.g.l. at Red River Landing, just prior to the main portion of the flood in the Red and the Ouachita. Thus the backwater was filled to this elevation before the highest discharges from the tributaries arrived in the backwater. This doubtlessly, in part, accounts for the slow fall also. If the Mississippi had been kept out, high backwater stages would not have endured so long and the Red and Black Rivers could not have filled the backwater to the stages attained. However, with the control structure in Old River, it is doubtful that the Mississippi River water would have been kept out of the area, if the principle of discharging into the Atchafalaya up to bankfull stage is adhered to. But even with the area filled to almost 45 ft. m.g.l. through the aid of flow from the Mississippi River, stages in the backwater area behind the ridges which parallel the banks of the main streams did not attain the stages registered in the main streams. For example, the highest stage at Acme in 1942 was 48.4 ft. m.g.l. and at Jonesville was 50.8 ft. m.g.l., yet a high-water gage on the bank of Bayou Cocodrie near Ferriday, La., registered a stage of about 46 ft. m.g.l. and a high-water gage on the east bank of Cocodrie Lake about 10 miles south of Jonesville, La., recorded a stage of about 45 ft. m.g.l. However, lands west of Black River and north of Red River were apparently inundated to approximately a 50-ft. m.g.l. elevation by water discharging from the Red River levee system at a relatively high stage.

The following stages give a general portrayal of conditions in this flood:

Location	Date	Stage, ft.
	Main Streams	
Simmesport	14 May	29.6 gage
Barbre Landing	14 May	36.4 m.g.l.
Acme	4-7 May	48.4 m.g.l.
Acme	14-16 May	47.7 m.g.l.
Jonesville	11-14 May	50.4 m.g.l.
Jonesville	17-20 May	50.8 m.g.l.

Location	Date	Stage, ft.
Tensas-Cocodrie Area		
Bayou Cocodrie near Ferriday	14 May	46.5 m.s.l.
Cocodrie Lake		45.6 m.s.l.
Landside, Mississippi River levee, near Slocum	14 May	46.1 m.s.l.
Mouth of Bayou Cocodrie	14 May	42.6 m.s.l.
Area West of Black River and North of Red River		
Mouth of Big Bayou Larto	14 May	50.53 m.g.l.
Mouth of Island Bayou (1 mile south of Sarena)	13 May	49.77 m.s.l.
Little River at Archie	13 May	51.03 m.s.l.
Big Bayou near junction with French Fork of Little River	13 May	51.04 m.s.l.
French Fork of Little River near Spencer Bayou	13 May	51.0 m.s.l.
Little River at Highway 19 northeast of Pollock	13 May	51.1 m.s.l.
Highway 471 near Big Saline Bayou	13 May	50.9 m.s.l.

Thus the 1942 flood in the Red and Ouachita Rivers did cause considerable flooding in the backwater area without material aid from the Mississippi River. Based upon the frequency curve at Alexandria, this flood appears to be approximately a 10-year flood.

In the 1942 flood, stages along the main streams in the backwater area were not sufficiently high to overflow the ridges next to the streams which constitute the main portion of the cultivated land. At Acme, the land along the left bank of the Black River is about 50 ft. m.g.l. and at Jonesville, the land contiguous to the streams is somewhat above 55 ft. m.g.l. With Old River closed with a control structure, operated as proposed, it is believed that the stage at Acme will not exceed 50 ft. m.g.l. more often than once in 20 to 25 years.

Necessity for protection against headwater floods. From the foregoing it is concluded that headwater flooding will not be extremely serious with Old River closed, but it will cause occasional damage which will result in a demand for protection. In addition, should the lower Red River channel and possibly the Black River channel deteriorate as previously suggested, headwater flooding conditions will be worsened and protection will become urgent.

Inclusion in over-all plan of levees in backwater area. The necessity for protection from headwater floods will not, it is believed, materially affect the desirability of closing Old River with a gated structure. The gates provide flexibility to the entire flood control project from Old River southward. But the levees required to give corresponding protection to that provided by other plans should be considered in comparing the economy of plans. That this will not unduly operate against the structure in Old River arises from the fact that a structure in Old River is believed to be required to prevent eventual capture of the Mississippi River. This structure to give positive guarantee of success must be founded deeply and must be provided with a stilling basin, apron or combination of the two. The cost of this structure will be a major portion of the cost of a control structure. The cost of this weir and ultimately a low head lock must be combined with the cost of large backwater protection levees to obtain the total cost of the plan. This then may be compared with the cost of the control structure in Old River, the relatively low levees that may be required to protect against headwater floods, and a high lift lock. The latter plan will provide partial protection to lands that cannot be inclosed by the backwater levees. This should be credited to the plan.

Conclusions. With the control structure in Old River, portions of the backwater area will, under present channel conditions, be subject to occasional flooding by headwater floods. The Tensas-Cocodrie area will be flooded to the 46-ft. level by headwater floods about once in 10 years, whereas under the authorized backwater levee plan, it will be flooded to this elevation about once in five years. Flooding to slightly higher elevations probably would be less frequent with the backwater levee plan than with control structure plan, for it has been indicated that headwater floods might cause a stage of 50 ft. m.g.l. at Acme which would probably be about 48 ft. within the Tensas-Cocodrie area about once in 20 or 25 years, whereas the sump level within the backwater levee would attain a stage of 48 ft. m.g.l. as a result of interior drainage about once in 40 years. However, the entire area would be flooded by overtopping of the Tensas-Cocodrie levee by Mississippi River backwater about once in 35 years unless the Morganza Floodway is operated prior to the overtopping of this levee, in which case frequency of flooding would depend upon the levee grade provided and might range from about once in 35 years to a considerably less frequent figure. With the control structure in Old River operated as contemplated, it appears that the Tensas-Cocodrie area would be flooded by backwater to about the same extent only once in 200 to 250 years.

Should channels in the backwater area deteriorate, headwater flooding may become serious.

Consideration should be given to the necessity for protection against headwater floods as a part of the plan for a control structure in Old River.

The over-all cost of this plan should be compared with the over-all cost of other plans giving corresponding protection with allowance for additional benefits that may be derived. When this is done, it is believed that the plan will not suffer in comparison with other plans. It may well be that the additional advantages will be the determining factors in favor of this plan.

The control structure will benefit lands which cannot economically be included within backwater levees.

The control structure will provide a flexibility in handling floods from Old River southward which cannot be had in any other way.

With the control structure plan, the backwater will still be available for reducing the discharge of the highest floods, for it is not contemplated that levees required for protection against headwater floods will be sufficiently high to prevent utilization of the backwater when needed. In fact, it is possible that a headwater levee plan may be devised which will make possible utilization of the storage in the low areas during moderate and moderately high floods. Such a levee plan would consist of levees which generally surround the several areas to be protected but which are not closed at the downstream ends. The openings would provide drainage without floodgates and would permit backwater flows as well as headwater flows to utilize the low areas. In fact, in special instances consideration could be given to providing a few openings at the upstream ends of some of these headwater levees, thereby permitting headwater flows to pass through the areas in limited amounts and be partially stored there. This would reduce the height of the headwater levees required and with proper design would still protect the higher and better land from headwater floods.

C. P. LINDNER
Lt. Col., Corps of Engineers

Memorandum from Brig. Gen. Hans Kramer to Brig. Gen. M. C. Tyler, President, M.R.C., 24 July 1945

SUBJECT: "Minority Report" on Proposed Control Structures at Old River and Morganza

1. **Statement of the problem.** The following is a resumé of the control problem for Old River and Morganza as you outlined it to me orally:

a. There is serious discrepancy between the discharge measurements of the Atchafalaya River during the 1945 flood and the quantities obtained from Mississippi River discharge and Red River backwater storage.

b. The increased discharge capacity of the Atchafalaya River indicates that the Atchafalaya is "pirating" the Mississippi River and may be on the verge (geologically) of becoming a main outlet to the sea, a repetition of geologic history of Mississippi River outlets and deltas. Such a switch must be prevented in order to maintain New Orleans and Baton Rouge as active river and seaports. Mississippi River flow below Old River should not be permitted to become less than bankfull (in flood season) in order to maintain a good main-stem river.

c. A controlled outlet structure near the confluence of Old River and Mississippi River to prevent excessive draft on the latter should, at the same time, reduce Red River backwater stages and possibly obviate the need for constructing the Tensas-Cocodrie project (authorized in the Act of August 18, 1941, at an estimated cost of $6,976,000, or protection of a larger area of Red River backwater at a total cost of not to exceed $14,000,000). This control structure could carry a roadway to connect with the lower end of the main line levee below Point Breeze. Such a modification could be authorized by the Chief of Engineers under the provisions of Section 3(c) of the Act of August 18, 1941.

d. A controlled outlet structure at the entrance to Morganza Floodway is authorized by law (Acts of June 15, 1936, and June 28, 1938). Such a structure could carry highway and railroad crossings, which still remain to be built for the Morganza Floodway, with possible economy in construction costs.

e. Mr. Moore's Design Division is working on some spillway designs and estimates. Lt. Col. Lindner is—and has been—working on the hydraulics. Mr. Schweizer has been checking the discharge measurements to discover probable sources of discrepancies.

f. Manual control of main river outlets is preferable to uncontrollable means such as crevassing or fuseplugs (which were dictated initially by considerations of economy) even at some appreciable, but not unreasonable, increase in cost.

g. Solving of the lower river flood outlet control is the major unsolved problem in the adopted project. (A control structure for Birds Point-New Madrid is of secondary importance and would probably follow upon successful solution of the lower river problem.)

2. **Mission.** The mission you gave me was to find the bugs in the statement and solution of the problem as outlined above; or, in other words, to study your proposal for faults rather than merits. I have made no attempt at a serious analysis of the hydrology other than the preparation and study of some flow diagrams and stage-discharge relations. Neither have I made any serious attempt at a hydraulic or structural design analysis of the proposed structures. My approach has been from a general engineering standpoint and from the viewpoint of the affected citizenry because, as in the case of the 1941 Report (H.D. 359, 77/1), "any further modification of the project, to be successful, must be based on considerations additional to those of engineering adequacy." Accordingly, my "minority report" comprises a philosophical as well as a broad engineering review of your propositions.

3. General characteristics of control structures

a. General. In viewing the merits and demerits of the proposed Old River and Morganza control structures, either separately or jointly, it is pertinent—because it is an important consideration additional to that of engineering adequacy and feasibility—to consider broadly the characteristics and behavior of control structures in their application to the adopted project.

b. Classification. For the purpose of this problem, control structures may be classified as follows:

I. Regulating type. Structures of this type consist of controllable devices such as fixed dams with gated sluices, a series of gates between successive piers, overflow structures with crest gates, movable dams with needles or wickets, etc. Their effective theoretical discharge is predetermined by design. Their actual discharge is governed by manipulation which involves perennial exercise of human judgment in determining the time and extent of operation.

II. Automatic type. Structures of this type consist of fixed dams with ~~ungated outlet conduits, ungated spillways with fixed crests including chute,~~ side-channel, siphon and shaft types, fixed dams with ungated overflow sections, etc. Overflow structures with automatic crest gates area special case under Type II. Human judgment enters only into the predetermination of design of Type II structures; it does not affect their operation thereafter. Inasmuch as they function automatically in consequence of natural events, their behavior is unvarying and unvariable.

III. Fuseplug type. These are usually substandard earth embankments or levees which are designed to fail or to be artificially breached under certain predetermined conditions. When deliberately designed they are dependent on human judgment for their characteristics but in cases where existing structures are arbitrarily designed as fuseplugs, they may be virtually devoid of formal design. Fuseplugs involve avulsive action which may require the application of human judgment and effort to initiate or accelerate actual failure. Thereupon their behavior is practically beyond control and unpredictable. Type I (gated) installations might be considered, in an extremely simplified sense, to be glorified fuseplugs.

IV. Composite type. Composite installations consisting of various combinations of Types I and II are used frequently to obtain a compromise solution for special problems.

c. Discussion

Type I. From an engineering standpoint Type I can be designed and operated to attain any desired degree or sequence of regulation. It is, of course, the most expensive type. It involves potential headaches from improper or ill-advised operation resulting from fallible human judgment in predicting future events. These headaches are pyramided when more than one structure of Type I is involved in a scheme of regulation. Elimination of this source of headaches is a constant concern in formulating operating programs for individual flood control reservoirs and series of reservoirs. The problem is troublesome enough in a single-purpose structure such as Bonnet Carre or Wappapello, but it is considerably worse in the case of a dual-purpose structure which involves conflicting interests. Though not designated as a dual-purpose structure, the proposed Old River outlet structure could be considered to belong in that category because it involves conflicting interests; viz., withholding outflow from the Mississippi by way of Old River in order to reduce Red River backwater stages versus increased flow (and higher stages) in the Mississippi River main stem, with consequent effects in the Lower Atchafalaya, if the diversion which is prevented at Old River is made at Morganza. In the lower Mississippi Valley the element of time is, of course, usually on the side of the human operator. Conditions are quite conceivable, however, under which the normally favorable time element would be considerably reduced if not entirely neutralized. Such a condition could readily have occurred in 1945 if the long period of dry, sunshiny weather which followed the record floods in the lower Red and Ouachita Basins had taken the form of additional severe storms.

Type II. Structures of this type do not permit variable operation and require more moral courage than Type I in the determination of their original self-regulating design. If rationally conceived and designed, however, this type of structure should serve entirely satisfactorily. The cost of Type II lies generally between Types I and III. The outstanding example of Type II is the system of flood control dams of the Miami Conservancy District whose simple and automatic functioning is widely recognized. Another example is Conchas Reservoir whose main dam spillway is designed to throttle ordinary floods down to bankfull channel capacity and the higher crested emergency spillway is designed to take care of major floods. Type II involves the exercise of human judgment but once. It seems logical that such a single judgment, deliberately arrived at, would be preferable to the perennial exercise of judgment, particularly under emergency conditions. Once built, Type II is foolproof.

Type III. The serious engineering and psychological disadvantages inherent to fuseplugs are so well recognized as to require little if any discussion. Experience at Birds Point in 1937 and the backing and filling at Morganza in 1945 speak for themselves. Fuseplugs may still be appropriate for backwater levees, e.g., White, Tensas-Cocodrie, but their uncertainty and unpredictability are out of keeping with the standards of engineering for the main Mississippi River project. In this connection I believe that early study should be given to the substitution of other structures for the fuseplugs at the head of the Birds Point-New Madrid and West Atchafalaya Floodways, so as to place control of these floodways on the same engineering plane that is contemplated for other parts of the adopted project in the current consideration of control structures at Morganza and Old River.

Type IV. The preliminary designs for the Morganza and Old River outlet structures contemplate composite types, in recognition of the principle that when extreme flood stages are approached control structures must be foolproof and entirely automatic in their functioning. In view of that principle, why should we borrow unnecessary trouble during lesser floods, or in the earlier stages of a project flood, by voluntarily saddling ourselves with adjustable devices which, by very virtue of their maneuverability, will certainly cause more or less public concern with resultant pressure, protests and criticisms from conflicting interests? In considering a composite type for any project structure, the project flood rather than lesser floods must be the governing criterion because of our over-all responsibility, under any reasonably conceivable circumstances, to insure the safety of the lower mainstem levee system by upstream diversion of waters in excess of 1,500,000 c.f.s. Any structure or device which is susceptible of producing an opposite effect, thereby "preventing or jeopardizing the diversions as contemplated in the adopted project," must be expected to be "viewed with alarm" by the populace and their representatives. The principle of automatic, foolproof operation for the superflood is engineeringly sound and generally acceptable to the public. The same principle should be applied as far as practicable to lesser floods which means, in terms of this discussion on types of control structures, a maximum use of Type II and a minimum of Type I in a composite design. I feel confident, even though I cannot prove the assertion, that once a rationally conceived and designed, practically automatic structure is approved and built, its subsequent functioning will be accepted as a matter of course, such acceptability increasing with the proportions of Type II.

d. Conclusions. From the above discussion it is fair to conclude that Type I is generally preferable to Type III, a conclusion which confirms the principle contained in the statement of the problem in paragraph 1f. However, my analysis further indicates the superiority of Type II structures over Type I for flood control installations. Type IV approaches Type II in superiority as the proportion of Type II is increased. My main conclusion with respect to the superiority of Type II is buttressed by, but not predicated on, an informal discussion between General Ferguson and myself during the recent Mississippi River Commission trip. In the course of our general conversation he remarked that the way to fix floodways is to install a simple inlet structure without gates or other devices which require manipulation— "then go away and forget it." As a corallary to this philosophy General Ferguson advocated letting some water into Government-controlled floodways even during minor floods in order to condition the populace to such usage. Although the foregoing was "just conversation" with General Ferguson it is deemed applicable to the present problem.

4. Pirating of the Mississippi by the Atchafalaya

a. Hypotheses. The statement of the problem in paragraph 1b contains two major premises as to the behavior of the Atchafalaya and its effect on the Mississippi, which constitute the primary basis for the proposed Old River control structure and a secondary basis for the Morganza structure, viz.,

(1) a serious pirating, accentuated by the 1945 flood, now exists or is imminent;

(2) this pirating condition dictates a need for artificial control in order to: (a) prevent the Atchafalaya from becoming the main river; (b) prevent the Lower Mississippi from deteriorating at and below bankfull stages.

b. Discussion. The following examination of the above hypotheses stems from an admittedly cursory review of discharge records, stage-discharge relations and other pertinent data and reports:

(1) Flood stages at Simmesport. An authoritative digest of the Atchafalaya's history and behavior during flood years from 1890 to 1940 is contained in Mr. Gerard H. Matthes' "Report on Atchafalaya River" dated 12 December 1940. It should be noted that at the time Mr. Matthes' report was written the construction of Wax Lake Outlet had not been completed. Mr. Matthes' report contains the following pertinent statements based on his study of flood data through the year 1939 with respect to stage-discharge relations at Simmesport:

"The river's flood stages at Simmesport have been reduced from 4 to 4-1/2 ft. since 1927, of which about half has been accomplished since 1932. However, flood stages still are about 5-1/2 ft. higher, for comparative discharges, than they were in 1890.

"The river's discharge capacity during very high flood stages at Simmesport has been increased between 1932 and 1939 by apparently 42,000 c.f.s. This is again of less than 10 percent over the discharge capacity which existed in 1890.

"It is probable that recent dredging operations have effected further increases in discharge capacity and in stage lowering, but these will not become known until some time during the coming flood season.

"Levee confinement, by causing scour, has materially improved navigable depths, but has raised flood stages and through slope flattening has retarded increase in discharge capacity.

"The rate of enlargement of the river channel as revealed by cross-section areas at first was rapid, but has slowed down to small proportions during the last few years. Except for important gains in the vicinity of Simmesport brought about by channel dredging, the tendency appears to be towards loss instead of gain during small-flood years. At any rate, the cross-section comparisons for 1937 and 1938 show noticeable decreases in some reaches.

"The evidence relating to channel cross sections and discharge capacity, taken together with the fact that cross-over bars are beginning to form above Woodside, are indicative that the river in its leveed channel is rapidly approaching stability as regards cross-sectional area, slope and stage-discharge relation.

"It is probable that the river, unassisted, may effect some further improvement in flood-stage lowering and possibly some cross-sectional enlargement should a series of heavy flood years ensue. If, on the contrary, years of small flood discharge should follow, there is probability that the river channel will tend to decrease in cross-sectional area as well as in discharge capacity.

"Future major enlargement of the river's flood discharge capacity by its own energy is obtainable only by lowering flood stages so as to bring more floodwater from the Mississippi River to the Atchafalaya. Since wholesale enlargement of the channel by dredging is prohibitive, the feasibility of such enlargement will depend mainly on what future flood flow, supplemented by corrective dredging, can accomplish."

Mr. Matthes concluded in his 1940 report that the Atchafalaya River in its upper reaches showed evidence of "channel maturity," i.e., stability. Rejection of this conclusion as of 1945 appears unwarranted in the absence of a comprehensive analysis of data for the intervening years. Unfortunately, I have not located in the Mississippi River Commission technical files any report or paper which extends Mr. Matthes' valuable study to cover similarly the flood years since 1939 which were marked by the completion of Wax Lake Outlet, the moderate floods of 1943 and 1944, and the major flood of 1945. Parenthetically, the lack of such a subsequent study in the form of a readily available formal paper constitutes a serious reflection on the thoroughness and continuity of Mississippi River Commission studies.

Accepting the latest correlation of data, which reconciles the apparent discrepancy in 1945 peak flow referred to in paragraph 1a, the Atchafalaya River at Simmesport discharged approximately 650,000 c.f.s. at a peak stage of 51.4 ft. on 28 April 1945. It should be noted that this 650,000 figure was an extreme reading and that other discharge measurements during the crest week while stages fluctuated only a few tenths ranged between 585,000 and 635,000 c.f.s. These data indicate that, although the instantaneous peak approximated 650,000 c.f.s., the protracted peak averaged about 620,000 c.f.s. From computations made in previous years it was anticipated that the flow through the Atchafalaya River at Simmesport at a stage approximating the 1945 peak would be between about 475,000 and 500,000 c.f.s., a figure which could be deduced also from a straight line projection of the stage-discharge relations for the peak conditions of 1937, 1939, 1943, and 1944. The fact that the 1945 measurement does not fit the straight line extrapolation but is, in fact, a substantial divergence from previous computations and records, is presumably the star witness in support of the premise that the Atchafalaya River is or is about to become a pirate. If the Atchafalaya River had behaved itself in accordance with previously established stage-discharge relations, it should have registered a peak discharge in substantial agreement with the design hypotheses of former years, or about 500,000 c.f.s. But the 1945 flow was actually measured at approximately 650,000 c.f.s. (and I am willing to accept that figure), an unexpected jump of 150,000 c.f.s.!

My explanation for this jump is that it is entirely logical for the projection of the stage-discharge relation curve to "flatten out" in reflection of the general increase in hydraulic efficiency produced by improvement dredging in the Atchafalaya Basin in recent years, and specifically because of the beneficial effect of opening Wax Lake Outlet which discharged 120,000 c.f.s. this year. (A simple illustration and rationalization of a similar phenomenon is the case of a full bathtub with one faucet running and the overflow drain operating so as to maintain a constant level in the tub. If the outflow rate be increased by also pulling the bottom drain plug, the inflow can be correspondingly increased without causing the water level to rise.) Another new condition, though probably not a major factor, which contributed to the increased discharge at Simmesport was the Carr Point Cutoff which was completed in 1944 and functioned in its first flood, with considerable enlargement, in 1945. The Carr Point Cutoff resulted in a small increase in entrance head and improved the hydraulic efficiency of the Mississippi end of Old River with some corresponding effect at the Atchafalaya end of Old River.

Although the foregoing analysis does not profess to be either profound or accurate in a quantitative sense, it is believed to be qualitatively rational. I am inclined to think that the unexpected increase in the Atchafalaya's discharge capacity as evidenced in 1945 would not have been so surprising, or be considered as serious evidence of pirating, if the model tests with which our office studies have been correlated in the past had been made on a model in which the hydrography of the Atchafalaya Basin had been remolded since 1937.

A corollary to my simplified explanation of the increased flood flow by way of the Atchafalaya River is that the improvement dredging operations in the Atchafalaya Basin, and particularly the dredging of Wax Lake Outlet, have been eminently successful. It follows, therefore, that their continuance and expansion, particularly with respect to Wax Lake Outlet, are deserving of further intensive study.

Another significant aspect of artificial control of the Old River-Mississippi bifurcation is the fact that the present project diversion at Old River of 550,000 c.f.s. is predicated on 650,000 c.f.s. being dischargeable through Morganza Floodway. Whereas some reliable data are available to substantiate the reasonableness of the projected Old River diversion, the project capacity of Morganza has not been similarly tested and remains, therefore, a purely theoretical quantity. It is quite possible, and not entirely unexpected, that Morganza's capacity will prove to be something less than 650,000 c.f.s. In that event, in order to control the project flood, Morganza's capacity will have to be increased artificially or an equivalent increase provided at Old River. Accomplishment of the latter objective would be seriously hampered, if not virtually blocked, if a regulating structure were then in existence. It would be prudent, therefore, regardless of all other considerations, to defer the planning of a control structure at Old River until the hydraulic characteristics of the Morganza Floodway are verified from some actual experience.

(2) Bankfull stages at Red River Landing. The hypothesis that outflow from the Mississippi River into Old River requires control at bankfull conditions in order to maintain satisfactory channel conditions below the point of diversion has been examined on the basis of Mississippi River Commission discharge records for approximate bankfull conditions at Old River Landing gage (bankfull stage equals 43 ft.) and at the Torras gage on Old River. As might be expected, these data are somewhat erratic and inconsistent and are

therefore susceptible of varying interpretations. However, the following statistics speak for themselves: For the period 1911 through 1945 the average diversion of Mississippi River flow into Old River at approximate bankfull stages was 16.2 percent, with a maximum of 24.6 percent in 1912 and a minimum of 4.9 percent in 1913; for the period 1911 through 1932 the average diversion was 15.8 percent; for the period 1933 through 1945, i.e., since commencement of improvement work in the Atchafalaya Basin, the average was 16.5 percent. The 1945 measurements, the first since creation of Carr Point Cutoff, showed a diversion of 19.7 percent. For comparative purposes it is noteworthy that for the project flood of 2,700,000 c.f.s. coming down the main river, a diversion of 550,000 c.f.s., or 20.4 percent, is intended at Old River and that, in 1945 with a flood of 1,900,000 c.f.s., the diversion actually amounted to 400,000 c.f.s., or 21.1 percent.

The above statistical record indicates that there has been no appreciable change in bankfull regimen and evidences no definite trend toward such a change. Therefore, if bankfull regimen is the governing criterion, no need for artificial regulation of diversion of flow at Old River is presently indicated in order to maintain satisfactory channel conditions in the lower Mississippi.

(3) Geologic theory vs. engineering facts. Frankly, I am not persuaded by the present evidence that there is any incipient danger of a change of regimen which would necessitate or justify artificial measures to control the Mississippi's outflow into Old River, either at bankfull or higher stages. It may be safe to say qualitatively that a pirating tendency is evidenced by previous geologic history, but for engineering purposes the premise of a dangerously active trend does not conform to the facts so far established. The bifurcation of the Mississippi River at Old River is behaving very satisfactorily at bankfull stages, and at higher flood stages is acting strictly in accordance with the design assumptions for the project flood. Why, then, should we engineer a structure which might prevent, by creation of artificial conditions, what is a reasonable certainty if present natural conditions remain undisturbed? The possibility that an engineering structure, either as the result of mechanical failure or because of faulty or ill-advised operating judgment which might be influenced by conflicting interests, could actually prevent the present unimpeded discharge into Old River with resultant hazards to the Lower Valley has been discussed in paragraph 3. Furthermore, why should we establish control of Old River, a decision which must be governed quantitatively by the assumed diversion capacity of the untried Morganza Floodway, and thereby build outselves into the position of jeopardizing our physical capability to carry out "the diversions contemplated in the adopted project through the Atchafalaya River and Atchafalaya Basin"?

If the increase in the Atchafalaya's discharge capacity, as indicated by stage-relation data at Simmesport in recent years, is to be regarded as primary evidence of an active geological evolution, such an interpretation would be tantamount to a repudiation of the engineering judgment which has determined the conduct of improvement operations in the Atchafalaya Basin since 1933. Without debating the geological theory as a long range proposition, the fact remains that what has happened is what was forced to happen by the works of man in our generation. Whether the improvement which has been caused by artificial means will remain constant for some time, or whether it will decrease or increase, will depend mainly on the frequency and magnitude of future floods which, of course, are unpredictable. It is premature and unwarranted at the present juncture, however, to conclude that the Atchafalaya is threatening to capture the Mississippi.

c. Conclusion. On the basis of the preceding analysis it is my conclusion that the pirating hypotheses stated in the problem are presently untenable.

5. Reactions of local interests. The following discussion is an attempt to analyze the probable reactions of local interests to the proposed Morganza and Old River control structures without, however, pretending to be a political prophet. These interests, all in Louisiana, may be grouped into three localities: (1) Red River Backwater; (2) Atchafalaya Basin with adjoining Teche and Lafourche Areas; (3) Mississippi River Main Stem below Morganza.

a. Morganza only. The Morganza Floodway, as such, is already generally accepted by all concerned, including the inhabitants of the Atchafalaya Basin whom it affects most adversely. A regulating structure of undetermined design to control inflow into the Morganza Floodway was indicated in the official Mississippi River Commission report and subsequent authorizing legislation. The ultimate installation of some form of inlet structure is therefore generally expected by the local interests. Accordingly, I believe that any proposal to implement the authorized plan by building such a structure, whether of Type I or Type II or of composite type (see paragraph 3), would educe general approval.

The Red River group would endorse it as a more positive means than the present fuseplug for obtaining desired lowering of backwater stages.

The Atchafalaya group would welcome it as a decided improvement over the present fuseplug whose prospective breaching during the 1945 flood caused serious apprehension (on the part of the citizenry!) as to the uncontrollable volume and duration of floodway discharge. However, if the proposal is presented primarily, or even secondarily, as a readier means for reducing Red River backwater stages, it would arouse opposition from the Atchafalaya group, notwithstanding the fact that the Mississippi River Commission Review Report of 1941 (H.D. 359-77/1) discusses possible diversion at Morganza during lesser floods.

The Mississippi Main-stem group, who are the principal beneficiaries under the Morganza Floodway, would approve it as a more reliable safety valve than the present fuseplug.

On the whole, therefore, public reaction should be preponderantly favorable to construction of control works at the head of Morganza Floodway as proposed in paragraph 1d.

b. Old River only. In the statement of the problem (paragraph 1c) it is considered that construction of a control outlet structure at Old River would constitute, within the meaning of the law, a permissible modification of the authorized levee plan for protection of the Red River backwater area, and that therefore it could be substituted at the discretion of the Chief of Engineers. The Flood Control Act of August 18, 1941, states in Section 3(c):

> ". . . the construction of a levee and improvements contemplated in the report of March 7, 1941, of the M.R.C. . . . for the protection of that part of the Red River backwater known as the Tensas-Cocodrie Area at an estimated cost of $6,976,000 is hereby authorized: . . . Provided, That the Chief of Engineers shall fix the grade of said levee, with a higher levee in his discretion, so that its construction will give the maximum practical protection without jeopardizing the safety and integrity of the main Mississippi River levee: . . . And Provided further, That . . . The Chief of Engineers may in his discretion substitute other levees and appurtenant works for, or make such modifications of, the levees and improvements herein authorized for the protection of the Tensas-Cocodrie area as may be found after further investigation to afford protection to a larger area in the Red River Backwater at a total cost not to exceed $14,000,000 and without jeopardizing the safety and integrity of the Main Mississippi River levees and without preventing or jeopardizing the diversion contemplated in the adopted project through the Atchafalaya River and Atchafalaya Basin."

The published report on which the 1941 law is based makes no mention of a control structure at Old River as an alternative to backwater protection by means of levees. "Other levees and appurtenant works" and "modifications" which may be substituted under the law connote conventional levees and appurtenant drainage structures. A major structure of a type entirely foreign to the legislation and to the engineering report upon which it is based could hardly be interpreted to be an appurtenant work or a modification, it being an entirely new departure. The report and the law merely cover the possibility of protecting a larger area by means of a more extensive and expensive levee system. Furthermore, the report and the law state specifically that such protection of backwater area must not endanger the main river levees below Morganza.

I would consider that the substitution of a previously unmentioned control structure for the authorized levee, no matter how justifiable economically or otherwise, is not within the power of modification delegated to the Chief of Engineers under the spirit and letter of the present law. Furthermore, I would consider that erection of a physical barrier at Old River to regulate the now-unrestricted flow from the Mississippi to the Red River backwater would create the physical possibility of permitting "the passage of water into the main river below Morganza Floodway in amounts materially exceeding those contemplated by the project, or deemed dangerous to safety."

On the basis of the preceding discussion it is my conclusion that the construction of outlet control works at Old River should and will require additional legislation. However, I do not consider that such a requirement would involve any serious difficulty. Even though competent legal opinion should differ from my interpretation of the law, it would be a censurable procedure to employ a technicality in order to side-step additional legislation in this case.

The Red River group, as a whole, except for minor navigation interests who might consider a navigation lock to be undesirable, would certainly find no basis for objecting to a control structure at Old River. Its potentiality for State highway development would be a favorable feature. Not having been reconciled (until their wetting of 1945) to the approved Tensas-Cocodrie levee plan, the Red River group would certainly favor a non-levee plan that would afford them equivalent or possibly even better flood protection. It should be noted, however, as discussed in Lt. Col. Lindner's Memorandum of 7 July 1945 and Supplement of 16 July 1945, that headwater floods combined with controlled backwater stages (and irrespective of his debatable point of channel deterioration) may cause a need for some levees in the Red River backwater even with a control structure at Old River. Though not entirely germane to this part of the discussion, it should be noted further that the Tensas-Cocodrie backwater levee constructed in accordance with existing authorization would constitute an additional factor of safety if and when an Old River control structure is built; the presently authorized cost differential of approximately $7,000,000 could be applied at that later date to help justify the Old River structure.

Inevitable increase in frequency of use of the Morganza and/or Bonnet Carre Floodways as the result of restriction of natural discharge from the Mississippi River into Old River would be obvious to the layman. Lt. Col. Lindner's memorandum of 7 July 1945 concludes that this increase in frequency would be from a four- to five-year interval under present conditions to about a three-year interval under controlled conditions. Therefore, the Morganza interests, notwithstanding the fact that the Government has obtained comprehensive easements over their lands, would have some basis for questioning the Government's representations in making its original acquisitions. As a corollary to increase frequency, the Atchafalaya group and the Main-stem group who are affected by Morganza and Bonnet Carre would object to the Old River control structure on the grounds of affording relief and protection to the Red River backwater group at the expense of more frequent floodway use and more frequent higher stages in the lower Main Stem and Atchafalaya. Added to this factual basis for opposition would be the psychological reaction to a structure which would be physically capable of overloading the main-stem flow in excess of the flow that would be possible under the adopted project without such a structure. Honest apprehension as to what can and may happen under the worst conditions of operation is not readily allayed by asserting that it is designed not to happen.

c. Morganza and Old River together. The foregoing summary of probable public reactions to control structures at Morganza and Old River as separate propositions indicates that a joint proposal would be all the more welcomed by the Red River group inasmuch as the individual structures are advantageous to them. The Atchafalaya and Main-stem groups, in considering the Morganza and Old River structures jointly, would undoubtedly feel that some sting had been taken out of the latter structure, but still not enough to make it palatable.

d. Discussion. In the preceding analysis and in paragraph 3, I have harped considerably—and perhaps too much so—on the fallible human element in the operation of adjustable flood outlets, either singly or in series. In so doing, however, I have been prompted by realism rather than pessimism in anticipating the reactions of John and Joe Citizen, et al. Flexibility of operation is not an asset per se; it may be a liability where serious conflicting interests can create pressure groups. Neither should flexibility be a cloak for indecision under the questionable philosophy that uncertainty at critical stages is indicative of a sound engineering solution. The fact that the Corps of Engineers can cite successful experience in the operation of several series of movable dams for navigation is, of course, a partial rebuttal. However, informed citizens and the engineering profession are well aware of potential and actual mismanagement in the operation of regulating structures for flood control. The magnitude of the consequences of such miscarriage upon the welfare of the Lower Mississippi Valley in time of major flood would, of course, be immeasurably greater than for any similar project elsewhere. Therefore, concern for public reaction and adherence to sound engineering dictate that the calculated risk be or approach zero.

e. Conclusions. My conclusions from the foregoing analysis and discussion are:

(1) Public opinion would be preponderantly in favor of a control structure at Morganza.

(2) Public opinion would be seriously divided on a control structure at Old River with the objectors in a strong majority.

(3) On a joint proposal, i.e., Morganza and Old River together, there would still be strong objection—probably strong enough to defeat the otherwise unobjectionable Morganza structure.

6. Model studies

a. Latest data. It is clearly indicated that whatever modifications of the adopted project may be embarked upon as the result of the current preliminary consideration of alternatives should be made the subject of comprehensive model studies. The existing Mississippi River Model which would be used for these studies is considerably out of date and should be rebuilt by applying data subsequent to the 1945 flood. The expense involved in getting new data, particularly for the Atchafalaya, is entirely consistent with the importance of such studies. The results of the model studies would be seriously questioned, if not entirely vitiated, if the latest conditions resulting from the greatest flood since 1927 were not faithfully reproduced in the model.

b. War game. As a new departure in the conduct of model studies which would attempt to simulate the element of human judgment in the operation of the model as it would enter into the operation of the prototype, a special series of tests should be conducted on the basis of a "war game." The conventional model testing procedure eliminates the element of human judgment by making the manipulation of the model a mechanical process on the part of the operator. In a war game the model operator would be given certain information from which to form his own estimate of the situation and make his own decision; thereupon this situation would be developed, and complicated, by new data furnished to the operator without advance notice. The operation of the model in such a war game might well be placed under the charge of Mr. Senour or Lt. Col. Lindner, with the President, Mississippi River Commission, acting as Controller. A carefully prepared and conducted war game should throw some light on the possibilities and the consequence of errors in human judgment which, as indicated in the discussion in paragraphs 3 and 5 above, are an important consideration in a broad evaluation of control structures.

7. **Findings and recommendations.** Summarizing the foregoing diagnosis results in the following findings and recommendations "from the minority viewpoint":

a. **Morganza.** A control structure for Morganza is engineeringly and legally sound, and undoubtedly acceptable to all concerned. Preliminary design studies, including up-to-date model tests, should be completed promptly with a view to appropriate public presentation of a well-prepared plan. The regulating installations should be of the automatic type as far as practicable. Negotiations should be resumed and pushed energetically to obtain the maximum advantage from the Morganza control structure in effecting uncompleted railroad and highway relocations.

b. **Old River.** Preliminary studies for a control structure at Old River which are now in progress should be brought to a suitable stage of completion, then suspended and filed for future reference. Plans for leveeing the Tensas-Cocodrie backwater area in accordance with existing authorization should be implemented without interruption. No proposal for a control structure at Old River should be presented for public consideration at this time because: (1) the engineering hypotheses for its need are seriously questionable; (2) unfavorable public reaction would jeopardize acceptance of the Morganza control structure; (3) the problem, if any, at Old River may change materially after actual use of Morganza Floodway and experience with its control structure.

HANS KRAMER
Brig. Gen., USA
Military Assistant

* * * *

MRC Memorandum Report on Protection of Red River Backwater by a Control Structure in Old River, and Operation of Morganza Floodway and Bonnet Carre Spillway, dated 13 August 1945

1. There appears to be a definite probability that in time the Mississippi River will be captured by the Atchafalaya River. The Atchafalaya has the advantage of a shorter course to the Gulf with consequent steeper gradient. Its carrying capacity has increased to a marked degree since 1930 both from natural causes and from dredging operations. Increase in discharge at various stages is shown on inclosure No. 1 herewith. The geological situation is covered by letter from Dr. H. N. Fisk, Consulting Geologist attached, inclosure No. 2.

2. Continued enlargement of the Atchafalaya River appears to offer the only promising means of lowering flood heights in the Red River backwater area.

3. It appears that such continued enlargement can be obtained by dredging operations if natural scour does not give the desired results.

4. The large increase in the Atchafalaya's capacity which showed up in the 1945 flood indicates that a point may have been reached where future enlargement may occur at an increasingly rapid rate.

5. If this is so, a control structure in Old River to prevent the capture of the Mississippi by the Atchafalaya may soon be a necessity.

6. Until a few years ago the adopted project contemplated disposition of the design flood of 3,000,000 c.f.s. at the latitude of Red River Landing, La., made up of 300,000 c.f.s. from the Red-Ouachita and 2,700,000 c.f.s. from the Mississippi as follows:

In the main river.	1,500,000 c.f.s.
In the Atchafalaya River	500,000 c.f.s.
In the Morganza Floodway.	650,000 c.f.s.
In West Atchafalaya Floodway	350,000 c.f.s.

However, the Morganza Floodway has never been operated so that as yet there is no certainty it will be able to extract 650,000 c.f.s. from the main river. Thus a more assured distribution made possible by development of the Atchafalaya River up to the present time is as follows:

In the main river.	1,500,000 c.f.s.
In the Atchafalaya River	600,000 c.f.s.
In Morganza Floodway	600,000 c.f.s.
In West Atchafalaya Floodway	300,000 c.f.s.

This condition would require a flow of 600,000 c.f.s. from the Mississippi River through Old River. A control structure in Old River under present conditions should therefore have a capacity, at project flood levels, of at least 600,000 c.f.s. Provision should also be made in the structure for enlargement of the Atchafalaya River's discharge capacity.

7. A preliminary layout and a sketch design are attached (inclosures Nos. 3 and 4) of a control structure having a capacity of 800,000 c.f.s. at project flood level in the Mississippi River. The structure is gated and will carry a two lane roadway which may be continued north to Ferriday on top of the main line levee. The estimated cost of the structure is $32,000,000.

8. With such a structure in operation the water level on the west (Old River) side can be held near or below elevation 45 m.g.l. at Barbre Landing, except in the great floods. Thus a high degree of protection from backwater flooding can be afforded the Red River backwater area by the structure. A map is attached showing in color the area of the Red River backwater lying below elevation 45 m.g.l. (inclosure No. 5).

9. If we assume control structures at Old River and at Morganza, we may assume an order of priority for the operation of the three structures, Old River, Morganza, Bonnet Carre. The 1945 operation of Bonnet Carre has caused complaints from oystermen in Lake Borgne and Mississippi Sound. Preliminary investigations by the Wildlife and Fisheries Bureau indicate that substantial damage to the oyster fisheries may have been caused by the operation of the spillway. If this proves to be the case we must expect opposition to the opening of the spillway in the future, if any other relief outlet is available.

Flowage has been acquired in the Morganza Floodway. It may be operated at any overbank stage of the Mississippi as soon as the highway and railway bridges and other structures are completed. The only objection to frequent operation of the Morganza Floodway is the possibility of loss of capacity through deposition of sand and silt. Whether this will occur can only be determined by actual operation.

10. If we assume the following sequence of operations:
    1. Discharge through structure at Old River limited to that which combined with Red-Ouachita flow will not raise Red River backwater above about 45 m.g.l. until Morganza is operating at full capacity.
    2. Morganza Floodway is operated up to full capacity.
    3. Old River structure is operated to hold flow below Morganza to 1,250,000 c.f.s.
    4. Old River structure is operated to hold flow below Morganza to 1,500,000 c.f.s. or less and Bonnet Carre is gradually opened to full capacity.

The frequencies, on the basis of past records, would be as follows: Red River backwater area would be flooded by backwater above about 45 m.g.l. at Barbre Landing once in 12 years; Morganza would be operated once in 3 years; and Bonnet Carre would be operated once in 9 years.

Frequency of flooding the Red River backwater to other elevations is shown on inclosure No. 6. It may be noted that with this plan the stage at Barbre Landing would reach 50 ft. m.g.l. once in 26 years. In the past this stage has occurred every 2 to 3 years.

11. The foregoing assumes a 4,775-ft. Bonnet Carre type structure (see inclosure No. 8) at the head of Morganza Floodway with sill at elevation 44 ft. m.g.l. The cost of this structure is estimated at $5,350,000 and the annual charges at $250,000.

12. So far as the rights of the Government are concerned, Morganza Floodway may be operated whenever the Mississippi River stage exceeds bankfull at the floodway entrance. Thus the front line levee could be taken down and the entrance left unencumbered. This would result in annual operation. Under the hypothetical plan of operation stated in paragraph 10 preceding it would not have to be operated every year, but on the average of once in 3 years instead. The latter frequency of operation can be obtained by the construction of a low levee at the entrance as well as by the installation of a needle or gated structure. In fact, use of a low levee at the entrance to control the frequency of operation of Morganza Floodway may be desirable. This levee entrance plan is shown on inclosure No. 9. The cost of degrading the existing levee and armoring the ends of that portion not degraded to limit scour is estimated at about $400,000 and the cost of replacing the low levee when it is washed out by operation of the floodway is estimated at about $110,000. The annual charges are estimated at about $65,000.

13. If a control structure were built in Old River, the authorized Tensas-Cocodrie levee could be dispensed with at a saving of about $7,000,000.

14. Existing law permits the expenditure of $14,000,000 for the protection of the Red River backwater. The control structure will cost $32,000,000 or $18,000,000 in excess of the authorization. Additional legislation would appear necessary. The benefits to the backwater as agricultural lands will not justify such an expenditure. However, it may be necessary to build such a structure to keep the Mississippi from going to the Gulf by way of the Atchafalaya. In that case the protection of the backwater becomes a by-product.

Improvement of the Lower Mississippi River for Flood Control and Navigation, May 1932 (Known as the "History of the Mississippi River Commission")

Atchafalaya River and Shreves Cutoff,
Vol. 1, pages 51-57

The most important outlet of the Mississippi River is the Atchafalaya River (also known to early writers as Atchafalaya Bayou or Bayou Pelousas). The head of the Atchafalaya River is shown on Plates IX and X. The origin of this stream has been the subject of considerable controversy. It was thought at one time that the Atchafalaya was an old mouth of the Mississippi, but this theory has since been discarded. Humphreys and Abbot believed (report of the Delta Survey) that the Atchafalaya was probably at first a drainage line which carried the runoff of a small basin to the Gulf of Mexico. They concluded that the discharge of Mississippi floodwaters into the Atchafalaya had set up erosion which ultimately joined the channels of the two streams, thereby making the Atchafalaya an "all-stage" outlet of the Mississippi. At present many geologists believe that the Black River (formed by the junction of the Ouachita and the Tensas) originally flowed down the present Atchafalaya channel and that the Red River found a channel to the sea farther to the west, possibly down the present Bayou Teche. Later changes, however, probably forced the Red to discharge into the Black River channel (as at present). The junction of the Mississippi and the Atchafalaya was probably formed by "break-through" at Turnbull Bend. Plate IX shows that in 1805 the Red River emptied into the Mississippi in the bight of Turnbull Bend, while the Atchafalaya debouched from the Mississippi a short distance below. The earliest map of the head of the Atchafalaya is that of the Monk Ptolemy who accompanied De Soto's expedition. Ptolemy's map, dated 1578, is said to show conclusively that the Atchafalaya then, as now, served as an outlet for the Mississippi River. No substantial changes appear to have occurred in the channel at the head of the Atchafalaya between 1578 and 1831.

The Atchafalaya, as it existed before 1831, was a great drift chute for the Red and Mississippi Rivers, and was, as a result, choked up by a compact floating mass of drift known as a "raft," the head of which was about 20 miles below the head of the river. This "raft" extended, with intervals of open water, for 20 miles down the channel. It was so dense that in some places willows grew upon it notwithstanding the fact that it was subject to stage changes.

The year 1831 was signalized by Shreves Cutoff, an artificial cutoff made across the neck of Turnbull Bend in the interests of navigation (see Plate IX). This cutoff is described later in this chapter. After Shreves Cutoff, the Red River flowed into the Mississippi generally through the upper branch of the old Turnbull Bend channel (then known as Upper Old River). The lower branch of the Turnbull Bend channel (then known as Lower Old River) deteriorated rapidly and in 1866 is reported as being grown up with timber near its mouth. The Upper Old River channel also deteriorated to such an extent that navigation was seriously hampered and was often virtually suspended during low water. In 1872 Red River abandoned the Upper Old River channel. Lower Old River channel thereupon reopened and now constitutes the connection between the Mississippi, Red, and Atchafalaya Rivers. This channel is known as "Old River." For a more detailed recital of these changes, the reader is referred to the Report of Major W. H. H. Benyaurd, Corps of Engineers (published in the Annual Report of the Chief of Engineers for 1880). The direction of the current through Old River changes with variations in the relative stages of the Mississippi and Atchafalaya Rivers.

After Shreves Cutoff, the Atchafalaya River raft ceased to grow, and in 1840 its removal was undertaken. The removal was completed by 1861. The removal of the raft and the extension of the Atchafalaya levees have been followed by a considerable enlargement in the channel of the Atchafalaya River (see discussion in Annual Report of the Chief of Engineers for 1906). The reasons for this enlargement are easy to understand. The removal of the raft increased the capacity of the existing Atchafalaya channel. The discharge of the river consequently increased and the development and extension of the existing Atchafalaya levee lines were the natural result. In its lower reaches the river, in its natural state, lost itself in a maze of tortuous waterways and tidal lakes whose channels had poor hydraulic properties. The levee lines have, however, confined the increased discharge of the river to one channel throughout the length of these lines. The enlargement of that channel was the inevitable result.

The character of the Atchafalaya River channel enlargement has been unusual. Excessive channel depth is usually associated with excessive width and the narrow reaches of the channel are comparatively shallow. Enlargement first manifests itself by scouring out deep, wide holes at frequent intervals in the channel. When the average channel cross section in any reach becomes large enough to accommodate the discharge of the river, these holes gradually fill up and a more uniform channel is developed. Subsequent enlargement consists mainly in an increase in widths, due to slow disintegration of the upper banks. This enlargement is, however, compensated for in some measure by a decrease in main channel depths. The extent of this channel enlargement is shown in Tables IV and V. Table IV illustrates the progressive increases in the maximum discharge of the river, while Table V illustrates the actual increases in channel cross section.

Table IV

ATCHAFALAYA RIVER, MAXIMUM DISCHARGES
(Measured near the Head of the River)

Year	Determined by	Discharge, c.f.s.
1851	Humphreys and Abbot	104,550
1858	Humphreys and Abbot	77,061
1873	U. S. Engineer Department	122,000
1882	Mississippi River Commission	280,600
1890	Mississippi River Commission	479,908
1912	Mississippi River Commission	412,545
1927	Mississippi River Commission	592,100

In considering Table IV, the fact must be borne in mind that the discharges given for 1882, 1890, 1912, and 1927 were materially affected by crevasses in the Atchafalaya levee system. In 1912 these crevasses were very extensive and the discharge measurement for that year is generally conceded to have been materially different from what it would have been had the flood been fully confined. The discharge measured in 1927 would probably have been considerably reduced had no crevasses occurred during that flood. The present maximum confined flood capacity of the Atchafalaya River is estimated at about 500,000 c.f.s.

Table V will be understood from inspection of the small scale map of the Atchafalaya River on Plate X. For convenience, the reaches from A to G, inclusive, shown in Table V are indicated on this map.

Table V indicates the extent to which channel enlargement has followed the extension of the Atchafalaya River levees. It will be noted that the channel enlargement reached its maximum in 1927 and that since that date there has been an appreciable deterioration in average channel cross section from reach A to reach E, inclusive. Reaches F and G have enlarged since 1927. This observed channel deterioration is readily explained by the fact that the year 1927 was an abnormal flood year which has until the present (December 31, 1931) been followed by only one flood (1929). The flood of 1927 caused a greater channel enlargement than the river could subsequently maintain. Deterioration was therefore inevitable. The fact that the channel through reaches F and G has continued to enlarge since 1927 is explained by the fact that these reaches are generally unleveed. The effect of the 1927 flood on the channel through these reaches was therefore much less pronounced than in the leveed reaches above.

In reach A, both banks were leveed in 1881, the time of the first comprehensive survey. The channel cross section in this reach has increased slowly since

Table V

ATCHAFALAYA RIVER
COMPARATIVE CHANNEL AREAS BELOW BANKFULL STAGE
Barbre Landing (0 Mile) to Butte La Rose (66.9 Miles)

Reach	Miles below Barbre Landing	Surveys 1880-81 sq. ft.	1904-05 sq. ft.	1916-17 sq. ft.	1927 sq. ft.	1931 sq. ft.
A	0-13.7	53,200	55,600	62,200	77,200	65,400
B	13.7-29.8	40,700	55,900	63,200	77,600	71,600
C	29.8-36.9	32,200	50,700	56,300	64,100	59,000
D	36.9-43.0	22,100	32,300	40,200	56,600	55,100
E	43.0-52.9		18,900	40,000	65,400	59,700
F	52.9-63.7		14,000	21,600	33,200	34,600
G	63.7-66.9		14,000	16,700	17,300	22,900

1881 as the channel below increased in capacity. By 1931 the average cross section in reach A was 23 percent greater than it was in 1881.

In 1881 reach B was leveed on the west bank only. Although the east bank levee was not extended past Melville until 1896, the average channel cross section in 1904 equalled that of reach A. The total increase in the average cross section of the channel in reach B was 76 percent between 1881 and 1931.

In 1881 reach C was entirely unleveed. By 1904 the levees had been extended to the southern limit of this reach, although they were not fully effective until the flood of 1903. The survey of 1904, however, showed the average cross-section area of the channel in this reach had increased by 57 percent over that of 1881. The major portion of this enlargement was probably the result of the concentration of discharge in the leveed reach above, rather than the result of levees in the reach itself. This enlargement made the cross-section capacity comparable with those of the reaches above. During subsequent years, channel enlargement in this reach has kept pace with that of reaches A and B. In 1931 the average cross-section area of reach C was 83 percent greater than in 1881.

Reach D was unleveed prior to 1904, but the survey of that year showed that its average channel cross section was 46 percent larger than in 1881. This increase is characteristic of the channel enlargement which takes place on this river for a few miles immediately below the lower end of the levee line. In 1904 the east bank of the reach was leveed and in 1908 the west bank levee line was completed. By 1931 the average cross-section area in this reach was about two and one-half times as great as it had been in 1881.

Reach E was entirely unleveed in 1904. Levees were, however, progressively extended down the west bank of the reach until by 1922 the levee line reached its present extent. By that year the east bank of the reach had also been partially leveed. By 1926 the east bank levee was complete throughout the reach. During the period 1904-1916 the average cross-section area more than doubled in this reach and the 1931 survey showed the average cross-section area to be more than three times as great as in 1904.

Reach F was unleveed in 1931 except for a very short east bank levee at the upper end of the reach. However, the levee lines in the reach above enlarged the average cross section in this reach by about 147 percent between 1904 and 1931.

Reach G is unleveed. The average section in this reach is considerably smaller than those of the upper reaches. The channel cross-section enlargement between 1904 and 1931 in this reach is about 60 percent.

The Atchafalaya River has been the subject of numerous studies and reports. The enlargement of the river has caused apprehension that the Mississippi River channel would deteriorate to a serious extent below Old River. This apprehension led to proposals for the separation of the two streams. A complete separation is, however, open to the serious objection that it would greatly increase the menace of Mississippi River floods below Old River. These studies are discussed in Chapter XI.

Fears for the deterioration of the Mississippi River channel have even extended to the belief that the main river might ultimately abandon its present channel and adopt that of the Atchafalaya. To prevent the further enlargement of the Atchafalaya channel, two sills were placed across the river at Simmesport, and an unsuccessful attempt was made to divert the Red River back into the Mississippi through the Upper Old River channel. These operations are discussed in Chapter XI and are indicated on Plate X.

The channel of the Mississippi River has in fact changed below the mouth of Old River since Shreves and Raccouri Cutoffs (these cutoffs are described later in this chapter). Tables VI, VII, and VIII illustrate the amount and character of the changes which have occurred. The reader is also referred to a report by the Mississippi River Commission on this subject under date of July 17, 1919, which appears in House Document No. 288, 66th Congress, 1st Session.

Table VI

MISSISSIPPI RIVER, AVERAGE CROSS-SECTION ELEMENTS FOR THE TWO-MILE REACH BELOW OLD RIVER

		Stage		
	Year	Bankfull	Medium	Low Water
	1882-3	4,138 ft.	4,003 ft.	3,299 ft.
	1895	4,277 ft.	4,140 ft.	3,687 ft.
Width	1910	4,559 ft.	4,424 ft.	3,812 ft.
	1922	4,631 ft.	4,513 ft.	3,738 ft.
	1923	4,612 ft.	4,471 ft.	3,665 ft.
	1924	4,673 ft.	4,525 ft.	3,689 ft.
	1882-3	237,860 sq. ft.	173,594 sq. ft.	75,178 sq. ft.
	1895	232,814 sq. ft.	163,410 sq. ft.	59,136 sq. ft.
Area	1910	226,857 sq. ft.	154,463 sq. ft.	43,066 sq. ft.
	1922	223,235 sq. ft.	150,147 sq. ft.	40,729 sq. ft.
	1923	227,312 sq. ft.	153,771 sq. ft.	44,441 sq. ft.
	1924	224,771 sq. ft.	151,171 sq. ft.	42,400 sq. ft.
	1882-3	57.7 ft.	43.5 ft.	23.4 ft.
	1895	54.4 ft.	39.5 ft.	16.2 ft.
Mean depth	1910	49.8 ft.	34.9 ft.	11.6 ft.
	1922	48.2 ft.	33.3 ft.	11.0 ft.
	1923	49.3 ft.	34.4 ft.	12.4 ft.
	1924	48.1 ft.	33.4 ft.	11.8 ft.

It will be noted that the limits of the reach considered in Table VII differ slightly from that covered by Table VIII. This has resulted in slight differences in

Table VII

MISSISSIPPI RIVER, COMPARISON OF CROSS-SECTION ELEMENTS
RED RIVER TO SCOTT BLUFFS (764 TO 827 MILES BELOW CAIRO)
Surveys 1882-83 and 1895

	Average Area, sq. ft.		Average Width, ft.		Average Mean Depth, ft.	
	1882-83	1895	1882-83	1895	1882-83	1895
Low-water stage	85,849	80,079	2,302	2,258	40.0	37.9
Change	-6.7%		-1.9%		-2.1 ft.	
Medium stage	157,267	151,318	3,220	3,265	51.4	48.2
Change	-3.8%		+1.4%		-3.2 ft.	
Bankfull stage	199,868	194,573	3,561	3,598	58.7	55.8
Change	-2.6%		+1.0%		-2.9 ft.	

Table VIII

MISSISSIPPI RIVER, COMPARISON OF CROSS-SECTION ELEMENTS
CARR POINT TO SCOTT BLUFFS (757.2 TO 828.6 MILES BELOW CAIRO)
Surveys 1895 and 1921

	Average Area, sq. ft.		Average Width, ft.		Average Mean Depth, ft.	
	1895	1921	1895	1921	1895	1921
Low-water stage	81,095	82,606	2,265	2,381	38.1	37.5
Change	+1.9%		+5.1%		-0.6 ft.	
Medium stage	151,235	154,259	3,256	3,254	48.5	50.2
Change	+2.0%		-0.1%		+1.7 ft.	
Bankfull stage	194,269	195,960	3,599	3,503	56.0	58.2
Change	+0.9%		-2.7%		+2.2 ft.	

channel cross sections and depths for 1895 as shown in the two tables. These differences are so slight, however, that they do not affect the conclusions drawn below.

Table VI indicates definite channel deterioration between 1882 and 1922 for the two-mile reach of the Mississippi immediately below Old River. Widths at low water, medium and bankfull stages increased during this period while depths and cross-section areas decreased. After 1922, however, progressive deterioration apparently ceased. The changes in cross-section elements after 1922 are those which might well be caused by unimportant and comparatively local conditions. Table VII illustrates the channel changes between 1882 and 1895 for the reach between the mouth of Old River and Scott Bluffs (see Plate X). This table indicates deterioration in this reach, but this deterioration apparently ceased before 1921 as is shown by Table VIII which indicates a fairly definite channel enlargement during the period 1895-1921. Scott Bluffs appears to be about the downstream limit of the effect of the Atchafalaya enlargement on the Mississippi River channel. Comparisons of cross-section elements for the reaches below Scott Bluffs reveal no evidences of channel deterioration.

The effect of the Atchafalaya upon the Mississippi River channel may be summarized as follows. The removal of the raft, and the extensive development of the Atchafalaya levees have caused an enormous enlargement of the channel and in the discharge capacity of the Atchafalaya River. Notwithstanding the enlargement of the

Atchafalaya, however, the deterioration in the Mississippi River channel below Old River has not been excessive, nor are there any reasonable grounds for apprehension that excessive deterioration may be expected in the future. The growth of the bar below the mouth of Old River may be partly due to the fact that Shreves and Raccourci Cutoffs changed this reach from a sharp bend with a concave bank on the east side to a more gentle bend with a concave bank on the west side. The crossing between this bend and the bend above is at about the mouth of Old River.

Below the lower limit of Atchafalaya levee influence, silting is taking place in the Atchafalaya Basin. This silting is probably more extensive now than it was before the channel enlargement permitted a marked increase in the volume of the Atchafalaya discharge. The Atchafalaya presents an interesting study in the development of an alluvial stream. The river is now silting up the existing Mississippi River delta which it must cross before it can push its own channel to the sea and undertake the construction of its own delta. At present the flow of the Atchafalaya is dissipated in a network of inefficient channels in the lower portions of the basin. When, however, this sedimentation has raised the surface of the basin to a sufficient elevation, the river will be forced to develop an efficient channel and push it to the sea. Until the Atchafalaya has formed such a channel, there is no apparent danger that the Mississippi will desert its present channel for that of the Atchafalaya. Should, however, any unforeseen circumstances render the Atchafalaya dangerous to the regimen of the Mississippi, there will be ample time to initiate protective works. No rapid changes are to be apprehended either in the Atchafalaya or the Mississippi River.

Vol. 1, page 49:

Accepted theory states that a sedimentary stream flowing in a bed of its own formation tends to adjust its cross section to the volume of its discharge. Accordingly, if part of the Mississippi is diverted through an outlet, a corresponding adjustment may normally be expected in the size and shape of the main channel below.

Vol. 1, page 60:

Much misinformation concerning Lower Mississippi River cutoffs exists in the popular mind, and engineers are by no means agreed as to their effects on the river channel. The layman usually visualizes a Lower Mississippi cutoff as a majestic phenomenon which occurs almost instantaneously and is followed by violent and stupendous river changes. This impression is fallacious. The speed at which a cutoff occurs depends upon the volume and velocity of flow and the character of the riverbanks. The formation of the initial cutoff channel may take place rapidly, but the creation of a set of conditions favorable to the formation of the cutoff channel, the enlargement of this channel to accommodate the entire discharge of the river, and the silting up of the old bend are all very gradual processes. In fact, a cutoff on the Lower Mississippi occurs so gradually that the complete estimate of its effects is a matter of exhaustive study rather than casual field observation.

Vol. 1, pages 69-70:

Shreves and Raccourci Cutoffs (Plates IX and XVIII) were both made artificially in the interests of navigation. The junction of the channels of the Mississippi, the Red, and the Atchafalaya Rivers as it existed before 1831 has been described earlier in this chapter. In the early years of the nineteenth century, the lower reaches of the Red River were shoaling badly and a bar was forming in the Mississippi below the mouth of the Red. These conditions seriously interfered with navigation and an artificial cutoff across Turnbull Bend Neck was proposed to improve the channel. The proponents of this scheme apparently hoped to improve not only the channel of the Mississippi but also the channel of the Red by this means. The theories underlying the anticipated improvement in the Red are not clear; however, Captain Shreve, the father of the Mississippi River steamboat, actively sponsored the idea and, when the cutoff was made in 1831, it was named for him. Shreves Cutoff shortened the river by about 15 miles. The effect of the cutoff upon the Red and Atchafalaya Rivers has been described earlier in this chapter.

Shreves Cutoff did not eliminate shoaling. It merely transferred the zone of shoaling to a new location on the Mississippi. Old River since 1831 has been the site of almost continual trouble in the maintenance of navigation. Although Shreves Cutoff demonstrated the ineffectiveness of the cutoff as a means of navigation improvement in this reach, resort was had to a second cutoff in 1848 at Raccourci Bend (4 miles below Shreves Cutoff) in an attempt to relieve the situation. Raccourci Cutoff was made by the State of Louisiana. The cutoff shortened the river by nineteen miles but failed to produce any improvement in the channel above.

As navigation improvements, Shreves and Raccourci Cutoffs must be classed as failures. Reference to Plate VI shows, however, that they were followed by no pronounced downstream channel changes. As will be seen later (under heading "Length of River Channel"), compensatory lengthening in the river channel following these two cutoffs has been very slow. Shreves and Raccourci may, therefore, be cited as two cutoffs which did not induce any pronounced channel changes.

The effects of these two cutoffs on floods have been widely discussed. Both Ellet's report and that of the Delta Survey discuss the cutoffs in some detail. Professor Caleb G. Forshey published a discussion of them in the Transactions, American Society of Civil Engineers, 1876. The conclusions of these early writers are based on fragmentary and inaccurate data, and cannot be regarded as either authoritative or conclusive. Although the cutoffs were attended by local readjustments of the channel, there is no conclusive evidence that they themselves have appreciably affected flood heights. The enlargement of the Atchafalaya cannot be considered the result of these cutoffs. As has been shown above, that enlargement was primarily the result of the destruction of the raft and the development of the Atchafalaya levees. Indeed, it is probable that Shreves Cutoff was an indirect benefit in the Atchafalaya problem. It interposed the inefficient Old River channel between the two rivers and trained the discharge of the Mississippi in such a direction that there has been no tendency on the part of that river to break through again into the Atchafalaya River channel. Had Shreves Cutoff not been made, it is possible that the removal of the Atchafalaya raft and the extension of the Atchafalaya levees would have been followed by a very serious diversion of Mississippi discharge.

Maintenance of Old River Navigation Channel between the Mississippi, Atchafalaya, and Red Rivers, from Annual Reports

The following chronology of events and dredging work performed in Old River, upper and lower arm of the abandoned bend circumscribing Turnbull's Island, following Shreves Cutoff in 1831 and in the Mississippi River per se near the mouth of Red River, all for the purpose of maintaining and/or improving navigation in Old River and/or lower Red River was obtained from a number of sources including reports of the Louisiana State Engineers, Annual Reports of the Chief of Engineers, and Special Reports by the Corps of Engineer Districts and the Mississippi River Commission.

1831, Shreves Cutoff on the Mississippi River

Prior to the construction of Shreves Cutoff in 1831 Red River entered Mississippi River in the upper portion of Turnbull Bend and the Atchafalaya was then an insignificant distributary of the Mississippi River from the lower portion of Turnbull

Bend. Navigation conditions in lower Red River were difficult due to drift wracks and other obstructions. Shreves Cutoff was constructed in 1831 for the specific purpose of improving navigation on the lower Red River. At this time, the upper portion of the Atchafalaya River was choked with drift and carried only a nominal amount of flow at high stages on the Mississippi River. Historians note that the stream was then so clogged with drift in times of low water that the drift wracks afforded passage for items and live stock.

Construction of Shreves Cutoff in 1831, see Plate B78, Appendix B, placed the mouth of the Red River and the head of the Atchafalaya in an abandoned Mississippi River Bendway channel. Following the construction of the 1831 cutoff rapid silting took place in both the upper and lower arms of the abandoned bend and by the low water of 1839 considerable difficulty was being experienced in maintaining a suitable navigation channel between the Mississippi and Red Rivers via the upper arm of the abandoned bend. During low water of 1845-47 low-water navigation between Red River and the Mississippi River was virtually suspended.

1864:

The upper arm of Old River was used by the Federal forces in their operations on Red and Black Rivers.

1866:

The lower arm of the abandoned bend had silted up and was supporting young timber growth.

1872:

Narrow channel scoured out through the lower arm of the abandoned bend (Old River) and some dredging work was performed in this channel by the State of Louisiana prior to 1887 when the United States initiated operations to maintain a navigable connection between the Mississippi, Red, and Atchafalaya Rivers.

1886:

Act of August 5 appropriated $187,500 for this work. A.R. 1888, page 2295.

1887:

The level of the bottom of Old River varied from about 4 ft. above the zero of Barbre gage to a few feet below. On December 31, 1887, during a rapid rise on Red River there was a water surface fall of 13 ft. from the Barbre gage to Red River Landing gage. The distance between these gages was 6 miles. This scoured Old River out sufficiently to provide a good navigation channel. A.R. 1888, page 2296.

1888:

The dredge *George F. Rootes* was employed from July 22 to November 6 and moved a total of 55,828 cu. yds. of material. The steamer *General Newton* was employed a few days in October 1888. The dredge *Nenge* arrived January 17, 1889, but did not work prior to May 31, 1889. A.R. 1889, page 2739.

July 1, 1889-July 1, 1890:

The low-water season was of short duration. The principal reliance was placed upon the dredge for maintaining a channel. The dredge *Pah-Ute* was moved to Upper Old River June 15 and worked until August 7. On August 28 the dredge began work in Lower Old River at Ash Cabin but was soon moved to the bar at the mouth. The total amount of material dredged in Lower Old River was 47,480 at a cost of 8.9 cents per yard. A.R. 1890, page 3336 (Plate 20).

June 1, 1890-May 31, 1891:

The dredge *Pah-Ute* worked from August 4 until September 8 when a good channel was secured. The average depth of Lower Old River increased during this period. The *Pah-Ute* excavated 23,492 cu. yd. at 13.7 cents. A.R. 1891, pages 3699 and 3701.

July 1, 1891-May 31, 1892:

"Another important change that has taken place since the cut-off is the general enlargement of the Atchafalaya in depth and width and its tendency to receive at certain stages the entire discharge of the Red River as well as a portion of that of the Mississippi. . . ."

Pah-Ute, 23,003 yd. at 3.5 cents, Sept. 22-Oct. 21, 1891
Menge, 54,291 yd. at 3 cents, Aug. 31-Sept. 22, 1891
Hayward, 13,179 yd. at 13.66 cents, Sept. 22-Oct. 21, 1891
Steamer *Florence* removed snags and old piling from Lower Old River during October 1891

A.R. 1892, pages 3208 and 3216.

June 1, 1892-May 31, 1893:

Pah-Ute, *Hayward* and *Herndon* began dredging September 5, 1892, and suspended operations October 1 when river stages became too low to permit operations. Dredge *Pah-Ute* worked on clay lumps between Ash Cabin and Dead Tree from December 4 to December 19, 1892. The bid, $69,500, of Bucyrus Steam Shovel and Dredge Company was accepted for the construction of a self-propelled 15-in. cutterhead dredge. A.R. 1893, pages 3818 and 3819.

June 1, 1893-May 31, 1894:

"During the falling stages of the river a considerable current existed in lower Old River toward the Mississippi, and the tug *Comstock* was sent up to assist scour and removal of sediment by steaming through back and forth over the shoal places and so stir up the sand by action of her wheel. The favorable condition of the current assisted by the tug resulted in there being no trouble in the channel from sand deposits."

Pah-Ute worked September 6 until November 2, 1893. Upon arrival, November 8, 1893, the new dredge was put to work in Lower Old River and continued until January 24, 1894. The report does not mention the name of the new dredge. Drawing ENG 53/3 of a dredge built by the Bucyrus people for the 4th District, Mississippi River Commission, carries the name the *Ram*. A.R. 1894, pages 2975, 2976 and drawing ENG 53/3. ("Ram" is the combination of the first letters in the words "Red," "Atchafalaya" and "Mississippi.")

June 1, 1894-May 1, 1895:

Dredge *Ram* was placed in operation in Lower Old River June 5, 1894, and dredged until January 4, 1895, moving 265,000 cu. yd. at a cost of 4.76 cents. The *Pah-Ute* started operation July 28, 1894, and continued until January 4, 1895, moving 50,000 yd. at a cost of 6.85 cents per yard. The lowest gage reading at Barbre Landing, Louisiana, was 1.61 ft. The controlling depth through Lower Old River during this low-water season was 4-1/2 ft. A.R. 1895, page 3860.

May 1, 1895-May 1, 1896:

The *Ram* was placed in operation May 31, 1895, and dredged as required until January 6, 1896. The lowest reading was 0.65 ft. on Red River Landing gage. The controlling depth was never less than 5-1/2 ft. A.R. 1896, page 3684.

May 1, 1896-May 1, 1897:

The only dredging required in Old River was across the bar at the mouth of Old River. A total of 13.8 10-hour days was worked moving 17,390 cu. yd. Dredging was also required near the head of the Atchafalaya River where a fill occurred during high water; 3,200 cu. yd of material were removed.

May 1, 1897-May 1, 1898:

Continued high stages on the Mississippi River and the resultant high velocities scoured a good channel through Old River. A total of 51,940 cu. yd. was removed by the *Ram* between September 5 and October 25. Dredging was done at the following locations, Mouth of Old River (Carr Point), Dead Tree Light, and Ash Cabin Light. A channel 7.5 ft. deep below the zero of Barbre Landing gage was maintained with exception of from 3 to 5 days when the controlling depth was 5.5 ft. at Dead Tree and Ash Cabin crossings. The cross-sectional area of Old River increased during high water (Plate 20).

June 1, 1898-June 1, 1899:

Dredge *Ram* worked 44 days between August 11 and November 17, moving an estimated 73,800 cu. yd. of material. A survey was made from Simmesport to Red River Landing. A comparison of 112 sections with the same section made in 1894 to a datum elevation of 35 ft. on the Barbre Landing gage showed the following: mean area increased from 20,901 sq. ft. in 1894 to 21,843 sq. ft. in 1899, mean depth increased from 26.6 ft. to 30.8 ft. and the mean width decreased from 793 ft. to 717 ft.

1900 period, ending May 31:

Ram commenced dredging July 29 and ended November 28, with 108,800 cu. yd. being removed at mouth of Old River, Dead Tree to Ash Cabin and Chandlers to the head of the Atchafalaya. The controlling depth during the low-water season was never less than 5-1/2 ft.

June 1, 1900-June 1, 1901:

Dredge *Ram* moved 60,000 cu. yd. from Lower Old River from August 20 to September 11. A channel of 5-1/2 ft. or more was maintained.

May 1, 1901-May 1, 1902:

Mouth of Old River required dredging. The *Ram* started August 9 and stopped August 27. A total of 57,333 cu. yd. of material was moved.

May 1, 1902-May 1, 1903:

During this period no dredging was done in Old River due to high river stages.

May 1, 1903-May 1, 1904:

No dredging was required in Old River.

May 1, 1904-May 1, 1905:

Dredge *Ram* worked from September 7 to October 4, making a 2100-ft. cut at the mouth of Old River and excavated 80,000 cu. yd. of material.

June 1, 1905-June 1, 1906:

Dredge *Ram* worked on the bar at the Mississippi River end of Old River from 21 to 27 September and 17 to 28 October, and moved some 28,385 cu. yd. of material.

June 1, 1906-June 1, 1907:

No dredging was required during this period. The following table indicates the results of operations to maintain a low-water navigation channel between the Mississippi River and the Red and Atchafalaya via Old River:

Year	Lowest Reading Red River Ldg. Gage, ft.	Lowest Reading Barbre Ldg. Gage, ft.	Old River Channel at Time of Lowest Stages
1879	0.5	N.R.	Closed
1880	6.1	5.0	Open
1881	3.4	-1.2	Closed
1882	9.1	8.6	Closed
1883	3.9	-0.4	Closed
1884	6.3	1.7	Open
1885	6.7	1.5	Open
1886	2.7	2.2	Closed
1887	0.5	0.0	Closed
1888	3.9	0.9	Open
1889	2.4	2.4	Partially open
1890	8.8	5.3	Open
1891	1.4	-0.1	Closed
1892	2.2	-0.2	Closed
1893	4.1	1.0	Open
1894	-0.2	-1.7	Open
1895	-0.6	-1.2	Open
1896	3.8	0.5	Open
1897	0.4	-1.8	Open
1898	9.5	7.1	Open
1899	1.0	-1.3	Open
1900	5.3	3.0	Open
1901	2.0	0.2	Open
1902	7.8	7.1	Open
1903	2.8	1.3	Open
1904	3.0	0.3	Open
1905	11.0	9.0	Open
1906	11.8	8.8	Open

A comparison of cross-section elements to 35 ft. on the Barbre Landing gage between the results of the 1894 survey and the 1906 survey indicated a decrease in the channel area and channel width, while the average channel depth increased.

June 1, 1907-June 1, 1908:

Dredging was initiated in Old River channel on September 24 and continued until October 10. The dredge cut was 100 ft. wide at the bottom and 1,250 ft. long, connecting deep water in the Mississippi River with deep water in Old River. The current was from the Mississippi River to the Atchafalaya River from June 15, 1906, to date of report. With a stage of 12.1 ft. on Red River Landing gage and 10.5 ft. on Barbre Landing gage, there was a controlling channel depth of 15 ft.

June 1, 1908-June 1, 1909:

On July 24 the current changed for the first time in two years and began to flow from the Atchafalaya toward the Mississippi and continued thus until September 1. With the current running from Atchafalaya to Mississippi, the natural channel was along the Torras shore. With the current running the other direction, the natural channel was around Carr Point. The *Ram* started dredging in the Torras channel on August 26 and worked there until September 1, when it was placed in the Carr Point channel. The *Ram* was placed on 24-hour operation on September 9. On 1 November the *Ram* was moved to the "Gut" to remove mud lumps and the *Gamma* started dredging the bar channel at Carr Point. The *Gamma* continued operations until December 9. The *Ram* worked in the "Gut" until November 22. The controlling depth was never less than 4-1/2 ft. The railroad transfer boat and barge, 90 x 400 ft., had difficulty getting through the channel and grounded frequently. The controlling section at zero mark on Barbre Landing gage was 420 sq. ft.

June 1, 1909-June 1, 1910:

Dredge *Ram* started work on the Carr Point entrance channel on August 17. The controlling depth was 9 ft. with Red River gage reading 22.4 ft. and Barbre Landing gage reading 20.4 ft. The dredge operated with a single crew until August 24 when it was placed in full operation until October 9. The controlling depth on October 9 was 12 ft., with Red River gage reading 5.4 ft. and Barbre Landing gage at 3.1 ft. The dredge unit moved to Angola Bar on the Mississippi River on October 9 and operated there until November 4. ~~The unit returned to Old River on November 5 to~~ work on the mud lumps 1/2 mile west of the Texas and Pacific Railroad bridge, and worked on these until November 20. The bucket dredge *Barataria* worked on the above-mentioned mud lumps from August 21 to September 16, removing 15,700 cu. yd. of material. From September 1, 1908, to June 1, 1910, the current was from the Mississippi to the Atchafalaya, except January 8-16, 1910, when there was no current. A comparison of 1908 and 1909 survey sections shows an increase of the hydraulic elements in Old River.

June 1, 1910-June 1, 1911:

Dredge *Ram* operated on the entrance bar from August 8 until October 5, 1910. A channel 150 ft. wide and 5 ft. below the zero of Red River gage was maintained. The flow was from the Mississippi River to the Atchafalaya River.

June 1, 1911-June 1, 1912:

Dredge *Ram* operated from June 16, 1911, until July 19. On June 16, there was a controlling depth of 10 ft. over the Carr Point entrance channel with Red River Landing gage reading 13.0 ft. The dredge operated from August 3 to August 25 when a channel 125 ft. wide and 15 ft. deep was obtained. The Red River Landing gage read 13.3 ft. on August 25. Some experimental dredging was conducted on the mud lumps below the Texas and Pacific Railroad bridge.

June 1, 1912-June 1, 1913:

On August 10, 1912, with 22 ft. on Red River Landing gage, the controlling depth over the entrance bar into Old River was 8 ft. Dredging by the *Ram* was initiated on August 10 and continued until September 23, when the controlling depth was 2-1/2 ft. below the zero of Red River Landing gage and width of 125 ft. was available. From June 1 until July 10 the current was from the Atchafalaya to the Mississippi. The rest of the period it was toward the Atchafalaya. Surveys of this year show a continued development of Old River. In 18 years, 1894 to 1912, the average cross section of Old River at 35 ft. on the Barbre gage increased 25 percent. Most of this enlargement has occurred in the last 4 years.

June 1, 1913-June 1, 1914:

Dredge *Ram* started operations on July 7. The controlling depth over the bar was 6 ft. for a distance of 1,000 ft. Operations were continued with double crew until August 18, when a depth of 10 ft. was secured with Red River Landing gage reading 8 ft. Dredging was resumed September 26 and suspended immediately during rise on Red River which reversed the current. The water surface slope toward the Mississippi River was 0.75 ft. per mile. The dredge *Ram* worked in the Carr Point channel, even though the reversed current placed the normal channel down through Torras Bar. Dredging was continued until December 4 when a rise in the Mississippi River rendered further dredging unnecessary. Surveys show a continued enlargement of Old River.

June 1, 1914-June 1, 1915:

Dredge *Ram* started operations on August 8. Due to the flow being from the Atchafalaya River the Carr Point channel was dry and an 8-ft. channel was available through the bar on the Torras shore. Dredging was commenced on the Carr Point channel. Operations with a double crew were carried on until September 30. The channel had a bottom width of 125 ft. and a depth of minus 5 ft. on the Red River Landing gage.

June 1, 1915-June 1, 1916:

Dredge *Ram* worked from September 28 to October 2 and October 23 to November 24, moving 86,400 cu. yd. of material. Surveys made indicated continued enlargement of Old River.

June 1, 1916-June 1, 1917:

Work began on the entrance bar August 21, 1916, and continued with short intermissions until October 28, 1916. The dredge cut was 1,260 ft. in length and 100,418 cu. yd. of material were dredged. Old River continued to enlarge. The 1916 flood caused extensive scour above, between and below the sill dams in the Atchafalaya River. Total expenditures for new work and maintenance to date of report was $1,295,908.65.

June 1, 1917-June 1, 1918:

With a stage of 21 ft. and a depth of 13.5 ft. over the entrance bar the dredge *Ram* commenced operations and continued until October 16, when the dredge broke down. One of the Mississippi River Commission dredges (name unknown) replaced the *Ram* after it broke down. A total of 147,398 cu. yd. was dredged. The enlargement of Old River continued.

June 1, 1918-June 1, 1919:

On July 1, 1918, the dredge *Ram* commenced operations on the entrance bar channel. With Red River Landing gage reading 12.4 ft., the controlling channel depth was 15 ft. The dredge operated until October 18 (one shift), with a 14-day shutdown for major repairs in July; 61,177 cu. yd. of material were removed.

June 1, 1919-June 30, 1920:

Dredge *Ram* operated over the entrance bar from August 6 until September 30. Dredge *Delatour* operated between 5 and 25 September. A channel 200 ft. wide and to the zero of Red River Landing gage and 125 ft. wide to -6 ft. on the gage was obtained. Dredging cost was $12,545.65. Surveys indicated that the sill dams were in bad condition and needed repair.

Note: Beginning with next item there was very little data given on results of surveys in Old River and in the Atchafalaya in the vicinity of the sill dams. Also there is no mention of a unit doing dredging in Old River.

F.Y. ending June 30, 1921:

Entrance to Lower Old River was maintained. Page 1988, A.R. OCE.

F.Y. ending June 30, 1922:

Dredging operations in Old River were carried on from July 18 to October 1 and from October 27 to November 15, 1921.

F.Y. ending June 30, 1923:

Dredging operations commenced on August 7, 1922, and were completed November 11, 1922. The channel was 1,650 ft. long; 82,858 cu. yd. of material were removed at a cost of $20,489.93. Total cost for year was $37,962.68.

F.Y. ending June 30, 1924:

Dredging at the entrance to Old River was commenced August 1, 1923, and completed December 8. The cut was 1,700 ft. long requiring the removal of 87,221 cu. yd. at a field cost of $20,293.62. Total expenditures to May 31, 1923, $1,551,101.40.

F.Y. ending June 30, 1925:

Dredging at the entrance to Old River commenced on September 16 and was completed November 29. The dredged channel was 800 ft. long, requiring the removal of 54,394 cu. yd. of material at a field cost of $17,102.74. Total cost during year was $28,996.66.

F.Y. ending June 30, 1926:

Dredging at the entrance to Old River was commenced on July 17, 1925, and completed August 22. During the period 33,883 cu. yd. were moved, at a cost of $13,417.18. The total cost for the period was $20,251.31, and to May 31, 1926, $1,600,350.37. The dredge *Ram* was employed on this work. Surveys made in September and October indicated that erosion had increased the area of the section over part of the sills.

F.Y. ending June 30, 1927:

Dredging was done at the entrance of Old River. It was commenced on July 1, 1926, and completed August 30, 1926; 37,127 cu. yd. of material were removed at a field cost of $7,787.11. The total cost during the year was $19,118.26; total cost to May 31, 1927, $1,569,812.53. No work was done on the sill dams as they were found to be in good condition.

F.Y. ending June 30, 1928:

No dredging was done at the entrance to Lower Old River. The least depth was 9.5 ft. with Angola gage reading 10.9. Minimum width of the 9-ft. channel at mouth of Old River was 300 ft.

F.Y. ending June 30, 1929:

No dredging was done in Old River.

F.Y. ending June 30, 1930:

No dredging was done in Old River.

F.Y. ending June 30, 1931:

Low-water stages prevailed on the Mississippi River during the past fiscal year over the longest period ever recorded; however, no minimum records were established. Dredging was done in Lower Old River during the year in maintaining the channel, at an expenditure of $10,033.18.

F.Y. ending June 30, 1932:

No dredging was done in Old River.

F.Y. ending June 30, 1933:

No dredging was done in Old River. In the lower Atchafalaya River 14 dredges, some part time, were engaged in experimental corrective dredging and channel improvement, with 3 cutoff channels excavated, i.e., 2,081,884 cu. yd. at Butte La Rose, opened March 20, 1933; 730,600 cu. yd. at Cow Island, opened December 23, 1932; and 138,158 cu. yd. at Bayou Chene, opened March 4, 1933. The following was also accomplished in the basin: Bayou La Rompe was enlarged at Mile 77, Splice Island, Mile 79, in Tensas Bay, was removed, and agitation was done from Cow Island Cutoff to head of Bayou Chene Cutoff.

F.Y. ending June 30, 1934:

Dredging near mouth of Old River was as follows:

Dredge *Todd*. . . . . October 1-5, 1933, 31,941 cu. yd.
Dredge *Waterway* . . . . June 9-15, 1934, 50,472 cu. yd.

F.Y. ending June 30, 1935:

The dredge *Todd* worked in the mouth of Old River August 15-24, 1934, moving 67,080 cu. yd. of material.

F.Y. ending June 30, 1936:

No dredging was required in Old River.

F.Y. ending June 30, 1937:

The dredge *Todd* worked in Old River August 12-18, 1936, moving 50,298 cu. yd. of material.

F.Y. ending June 30, 1938:

No dredging was required in Old River.

F.Y. ending June 30, 1939:

No dredging was required in Old River.

F.Y. ending June 30, 1940:

No dredging was required in Old River.

F.Y. ending June 30, 1945:

Carr Point Cutoff opened November 8, 1944. (Plate 21)

F.Y. ending June 30, 1946:

A sand fill was constructed across the abandoned arm of Old River. Work with fill was completed March 1946. (Plate 21)