

the Secretary of War the bridge as constructed provides suitable and proper facilities for present and prospective navigation.

Right to sell, etc.,  
conferred.

SEC. 2. The right to sell, assign, transfer, and mortgage all the rights, powers, and privileges conferred by this Act is hereby granted to the Chicago and North Western Railway Company, its successors and assigns, and any corporation to which such rights, powers, and privileges may be sold, assigned, or transferred, or which shall acquire the same by mortgage foreclosure or otherwise is hereby authorized to exercise the same as fully as though conferred herein directly upon such corporation.

Amendment.

SEC. 3. The right to alter, amend, or repeal this Act is hereby expressly reserved.

Approved, January 21, 1927.

January 21, 1927.  
[H. R. 14236.]  
[Public, No. 559.]

CHAP. 46.—An Act Granting the consent of Congress to the police jury of Rapides Parish, Louisiana, to construct a bridge across Red River at or near Boyce, Louisiana.

Red River.  
Rapides Parish, La.,  
may bridge, at Boyce.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the consent of Congress is hereby granted to the police jury of Rapides Parish, Louisiana, its successors and assigns, to construct, maintain, and operate a bridge and approaches thereto across the Red River at a point suitable to the interests of navigation at or near Boyce, Louisiana, in the parish of Rapides, in the State of Louisiana, in accordance with the provisions of an Act entitled, "An Act to regulate the construction of bridges over navigable waters," approved March 23, 1906, and subject to the conditions and limitations contained in this Act.

Construction.  
Vol. 34, p. 84.

Rates of toll to pro-  
vide sinking fund, etc.

SEC. 2. If tolls are charged for the use of such bridge, the rates of toll shall be so adjusted as to provide a fund sufficient to pay the cost of maintaining, repairing, and operating the bridge and its approaches, and to provide a sinking fund sufficient to amortize the cost of the bridge and its approaches as soon as possible under reasonable charges, but within a period of not to exceed thirty years from the completion thereof. After a sinking fund sufficient to pay the cost of constructing the bridge and its approaches shall have been provided, such bridge shall thereafter be maintained and operated free of tolls, or the rates of tolls shall thereafter be so adjusted as to provide a fund of not to exceed the amount necessary for the proper care, repair, maintenance, and operation of the bridge and its approaches. An accurate record of the cost of the bridge and its approaches, the expenditures for operating, repairing, and maintaining the same, and of the daily tolls collected shall be kept, and shall be available for the information of all persons interested.

Operation as free  
bridge, etc., after pay-  
ment of construction of  
cost.

Record of expendi-  
tures and receipts.

Amendment.

SEC. 3. The right to alter, amend, or repeal this Act is hereby expressly reserved.

Approved, January 21, 1927.

January 21, 1927.  
[H. R. 11616.]  
[Public, No. 560.]

CHAP. 47.—An Act Authorizing the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes.

Rivers and harbors  
improvements.  
Work authorized.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the following works of improvement are hereby adopted and authorized, to be prosecuted under the direction of the Secretary of War and supervision of the Chief of Engineers, in accordance with the plans recommended in the reports hereinafter designated:

Waccamaw River, S. C. Survey to remove shoals.	That a survey be made of the shoals near Red Bluff, on the Waccamaw River near Conway, South Carolina, by the War Department, for the purpose of removing said shoals, and that such survey and report thereon be made to the Secretary of War not later than April 1, 1927.
Savannah, Ga.	Savannah Harbor, Georgia, in accordance with the reports submitted in House Documents Numbered 261 and 262, Sixty-ninth Congress, first session, and subject to the conditions set forth in said documents.
Apalachicola Bay, Fla.	Apalachicola Bay, Florida: The modification of the existing project recommended in House Document Numbered 106, Sixty-ninth Congress, first session, is hereby authorized.
Inland waterway, Jacksonville to Miami, Fla.	Inland waterway in general seventy-five feet wide and eight feet deep at local mean low water following the coastal route from Jacksonville, Florida, to Miami, Florida, in accordance with the report submitted December 14, 1926, in House Document Numbered 586, Sixty-ninth Congress, second session, and subject to the conditions set forth in said document.
Anclote River, Fla.	Anclote River, Florida, in accordance with House Document Numbered 18, Sixty-third Congress, first session.
Gulfport and Ship Island Pass, Miss. Relocation of chan- nel.	Gulfport Harbor and Ship Island Pass, Mississippi: The present adopted project may be modified by relocation of the channel across Ship Island Bar at such point as the Chief of Engineers, United States Army, may deem most desirable in the interest of navigation and economy.
Amite River and Bayou Manchac, La.	Amite River and Bayou Manchac, Louisiana, in accordance with the report submitted in House Document Numbered 473, Sixty-eighth Congress, second session.
Little Caillou Bayou, La.	Little Caillou Bayou, Louisiana, in accordance with the report submitted in Rivers and Harbors Committee Document Numbered 5, Sixty-ninth Congress, first session, and subject to the conditions set forth in said report.
Bayou Bonfouca, La.	Bayou Bonfouca, Louisiana, in accordance with the report submitted in House Document Numbered 474, Sixty-eighth Congress, second session, and subject to the conditions set forth in said document.
Mississippi River. Cairo to Head of Passes. Project modified.	Mississippi River between Cairo and the Head of Passes: The existing project is hereby modified in accordance with the report submitted in House Document Numbered 105, Sixty-ninth Congress, first session.
Saint. Louis to the Ohio. Project modified.	Mississippi River from the northern boundary of the city of Saint Louis to the mouth of the Ohio. The existing project is hereby modified in accordance with the recommendations submitted by the Chief of Engineers in letter to the chairman of the Rivers and Harbors Committee of the House of Representatives, dated December 17, 1926, contained in House Document Numbered 9, Sixty-ninth Congress, second session.
Louisiana and Texas Intracoastal Water- way. New Orleans, La., to Corpus Christi, Tex.	The Louisiana and Texas Intracoastal Waterway, from the Mississippi River at or near New Orleans, Louisiana, to Corpus Christi, Texas, in accordance with the report submitted in House Document Numbered 238, Sixty-eighth Congress, first session, and subject to the conditions set forth in said document: <i>Provided however</i> , That the section from Galveston to the vicinity of Gulf, Texas, shall be constructed as recommended by the Board of Engineers for Rivers and Harbors in its report contained in the said document: <i>Provided further</i> , That not more than two Government dredges shall be constructed for use in prosecuting this project: <i>And provided further</i> , That no expense shall be incurred by the United States for the acquiring of any lands required for the purpose of this improvement.
Provisos. Galveston to Gulf, Tex.	
Dredges limited.	
No expense for lands.	

MISSISSIPPI RIVER BETWEEN THE OHIO RIVER AND  
ST. LOUIS

LETTER

FROM THE

CHIEF OF ENGINEERS, UNITED STATES ARMY

TRANSMITTING

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND  
HARBORS ON REVIEW OF REPORTS HERETOFORE MADE ON  
MISSISSIPPI RIVER BETWEEN THE MOUTH OF THE OHIO  
RIVER AND THE NORTHERN BOUNDARY OF THE CITY OF  
ST. LOUIS

WAR DEPARTMENT,  
OFFICE OF THE CHIEF OF ENGINEERS,  
Washington, December 17, 1926.

HON. S. WALLACE DEMPSEY,  
*Chairman Committee on Rivers and Harbors,*  
*House of Representatives.*

DEAR SIR: 1. Referring to letter of the chairman of the Committee on Rivers and Harbors of the House of Representatives, dated March 28, 1924, inclosing a copy of a resolution of the committee requesting the Board of Engineers for Rivers and Harbors to review the project heretofore adopted by Congress for the improvement of the Mississippi River between the mouth of the Ohio and the northern boundary of the city of St. Louis, with a view to providing a permanent, navigable channel, with a minimum depth of not less than 9 feet and a minimum width of not less than 300 feet, with sufficient width of said channel around the bends in said river to afford convenient passage for tows of barges used on the Mississippi River, I inclose herewith the report of the board thereon, dated December 15, 1926.

2. This section of the Mississippi River is under improvement by the United States for the provision of a channel with a minimum width of 200 feet and a depth of 8 feet from the Ohio River to St. Louis, and thence 6 feet to the mouth of the Missouri River, to be obtained by regulating works and dredging. Between the time of the adoption of the project in 1910 and the end of the fiscal year 1925, \$2,593,920 was expended for new work. Since that time allotments

These works will, he believes, provide a channel 9 feet deep and not less than 300 feet wide. The total estimated cost, including amounts made available since 1910, is \$31,000,000. There has already been made available \$6,100,000, leaving for future appropriation or allotment \$24,900,000. The annual maintenance cost is estimated at \$900,000, which is \$300,000 greater than the present annual expenditure for that purpose. He recommends that the regulating works and revetment be completed and that dredging, which affords only temporary relief, be resorted to only when and to the extent that the needs of navigation then existing require. The division engineer concurs.

7. The board points out that this section of the Mississippi already carries a commerce of some magnitude. The development of transportation on the upper Mississippi River will probably add to this tonnage, and completion of the Missouri River improvement to Kansas City will add an appreciable traffic having its origin or destination on the lower river. A 9-foot channel has recently been recommended in the Illinois River, with a view to providing a through waterway of that depth from the Lakes to the Gulf. The board therefore concludes that the provision of a 9-foot depth in this section of the Mississippi is essential. In view of the results already obtained from the works thus far carried out and from a study of the plans proposed by the district engineer, the board believes that a continuation of the present method of improvement will provide the channel dimensions desired. It therefore recommends modification of the existing project for the Mississippi River between the mouth of the Ohio and the Missouri, so as to provide for a channel 9 feet deep and generally 300 feet wide, widened at the bends, up to the northern boundary of the city of St. Louis, by contraction works and bank revetment, together with such dredging as may be necessary, at an estimated cost of \$31,000,000, including amounts expended and allotted since 1910, with \$900,000 annually for maintenance. Funds should be made available as needed.

8. After consideration of the above-mentioned reports, I concur in general with the board.

9. The shoals in the section of the river between the mouth of the Ohio and St. Louis have been attacked successfully in the upper 100 miles of the section and a depth of 8 feet or more has been maintained almost continuously since January 1 of this year. Additional works are needed from time to time in the process of molding the stream so as to hold the channel in a permanent position. The shoals in the remaining 80 miles of the section are being similarly attacked. Part of the success in maintaining existing channels during the present year has been due to high water and other favorable conditions, but much of it can be credited to the works already constructed.

10. There is at present a 9-foot project for the Ohio and for the Mississippi River to the mouth of the Ohio, and the large and constantly increasing commerce on the river requires that a channel of this depth be extended to St. Louis. Congress is at the present time giving consideration in the pending river and harbor bill to the recommendation for a 9-foot channel in the Illinois River, and studies are being made by the War Department with a view to recommending a 9-foot channel from St. Louis to the mouth of the Illinois. It is very desirable that there be provided ultimately a continuous channel



200 feet and a depth of 8 feet from the Ohio River to St. Louis, and 6 feet from St. Louis to the mouth of the Missouri River, to be obtained by regulating works and dredging as follows:

First. By regulating works, for closing sloughs and secondary channels, narrowing the river to a uniform width of about 2,500 feet at bank-full stage, building new banks where the natural width is excessive, and by protecting new and old banks from erosion where necessary to secure permanency.

Second. By dredging or other temporary expedients, pending the completion of the permanent improvement, so as to maintain each season the required low-water depth of channel. This project was originally adopted in 1881, was later superseded, and finally re-adopted in 1910. Between the latter date and the end of the fiscal year 1925, \$2,592,920 was expended for new work. Allotments totaling \$3,500,000 have been made since that time for new work. The estimated cost of the work, made in 1910, was \$21,000,000, exclusive of amounts previously expended.

3. The commerce on this section of the river in 1925, exclusive of car and general ferry traffic and of sand moved short distances, was 1,004,000 tons. Inclusive of ferry and other local traffic the total was nearly 9,000,000 tons. An economic study was made by the district engineer, with a view to estimating the potential tonnage which might develop on the improved channel and the probable savings in transportation costs which would result. An analysis was made of all the freight moved in the Mississippi Valley in 1924 in directions favorable for transportation on the river. A computation of savings resulting from the diversion from rail to water of certain of this traffic was based in general on a comparison of the existing freight tariffs by rail and by river. Where river tariffs did not exist, they were constructed on the basis of 80 per cent of the port-to-port rail rate. The district engineer concludes from this study that a total of 6,680,000 tons of commerce may develop on the river at a computed saving of \$4,453,950. No distinction has been made by the district engineer between the possibilities of an 8-foot and a 9-foot channel, it being believed that the principal feature affecting the development of a large tonnage is a dependable channel of navigable depth. Equipment already operating on the river is suitable for use on either an 8-foot or 9-foot project.

4. The middle Mississippi, as the section between the mouth of the Ohio and the mouth of the Missouri Rivers is generally known, has characteristics which largely resemble those of the Missouri. For 134 miles below St. Louis, the river flows through an alluvial valley generally 4 to 5 miles wide between the bluffs. In the 7-mile section between Grays Point and Commerce the river passes through a rock-bound gorge, from which it emerges into the wide deltalike valley of the lower Mississippi. The river stages are affected by the combined flow of the upper Mississippi and the Missouri, and by the retarding effect of the Ohio River, which varies with the stage. The bed of the river is composed of various materials from the extreme of ledge rock to the finest of silt. Vast deposits of silt are brought in from the Missouri River and its free movement during floods has a controlling effect on the location and depth of channels across the bars. The low-water flow at St. Louis is about 40,000 second-feet, not including the water diverted from Lake Michigan through the Chicago Drainage Canal and the Illinois River. Practically no sediment is carried

His calculations, and the results of work already done, indicate to him that this plan will provide a channel 9 feet deep and not less than 300 feet wide. He divides the work into classes on the basis of necessary priorities, as follows:

(a) Structures required now to protect caving banks and to remove shoals in the channel, estimated to cost \$12,600,000, less expenditures already made and funds available, leaving \$6,500,000 yet to be provided.

(b) Structures required in the near future to complete regulation of the river, estimated at \$9,700,000.

(c) Structures required, but not immediately, to complete the work, at an estimated cost of \$8,700,000.

The total estimated cost, including funds made available since 1910, is \$31,000,000, an increase of \$10,000,000 over the estimate at that time for work still to be done. Of this sum there has already been made available \$6,100,000, leaving for future appropriation or allotment \$24,900,000. Annual maintenance of the work is estimated at \$900,000; \$600,000 for maintaining regulating works and \$300,000 for dredging. This is \$300,000 greater than the present annual expenditure for maintenance.

8. The rapid development of the lower Mississippi Valley and the Southwest assures, in the opinion of the district engineer, a growing demand for transportation in this region. For this purpose and to provide adequately for the traffic already existing a stable channel of reasonable dimensions at all river stages is demanded. He points out that failure to carry on the improvement of the middle Mississippi would eventually result in a controlling depth of 4 or 5 feet and in the destruction of valuable land, due to vagaries of the channel. He recommends:

(a) That the regulating works and revetment now being carried on be completed.

(b) That until the regulating works have been completed a channel 8 feet deep and generally 200 feet wide be maintained by dredging.

(c) That dredging be continued as needed to maintain a channel 9 feet deep and generally 300 feet wide, provided that a channel depth greater than 8 feet and a width greater than 200 feet should be provided only when the needs of navigation then existing are not adequately met by a channel of those dimensions.

(d) That all regulating works below St. Louis be completed before new works above St. Louis are undertaken.

The division engineer concurs.

9. This section of the Mississippi River already carries a commerce of some magnitude. Completion of the Missouri River improvement to Kansas City will add an appreciable tonnage, having its origin or destination on the lower river. Developments in transportation on the upper Mississippi River will probably still further add to the tonnage of the middle Mississippi. A 9-foot channel has recently been recommended in the Illinois River, with a view to providing a through waterway of that depth from the Great Lakes to the Gulf. All of these considerations point to the necessity for continued improvement of the section of the Mississippi under consideration and to provision of a channel of 9-foot depth. The results already obtained from the contraction works and bank revetments thus far placed, and a study of the plans proposed by the district engineer show that a continua-

2. The plans and projects originally adopted for the general improvement of this portion of the Mississippi River (between the mouths of Ohio and Missouri Rivers) have been somewhat modified but not radically departed from. The first Federal work toward improving the Mississippi, the destruction of snags and trees endangering navigation between New Orleans and the mouth of Missouri River, was authorized by act of Congress, May 24, 1824, the initial appropriation being \$75,000. The snagging then inaugurated was interrupted during the Mexican and Civil Wars but was resumed in 1866 and has been continuous ever since. The first work in the nature of permanent improvement, "a pier to give direction to the current of the Mississippi River, near the city of St. Louis," was authorized in acts of Congress, July 4, 1836, and March 3, 1837, which appropriated a total of \$50,000 therefor; and in 1844 the sum of \$25,000 was appropriated for the benefit of navigation in St. Louis Harbor. The amounts expended under these old appropriations are not available for citation here.

3. The first project report pertaining to the general improvement of the river in this district was submitted to the Chief of Engineers, United States Army, by a board of Engineers April 13, 1872, for proposed works between the mouth of Meramec River and Alton, Ill. The board stated as its belief that the ultimate demands of commerce would require the low-water width of St. Louis Harbor to be not over 1,200 or 1,500 feet. The works, begun in 1872 and continued for a number of years, consisted of solid dikes and dams of brush and stone, to confine the low-water flow of the river to a single channel, and revetments of brush mattress and stone paving to hold and preserve the banks from erosion. Eight-foot navigation between the mouth of Ohio River and St. Louis and 6-foot navigation thence to the mouth of Illinois River were first recommended in a report by the district engineer on transportation routes to the seaboard January 20, 1875, these channels to be obtained in four years and total cost estimated at \$7,159,200.

4. The present project, using revetments as in 1872 and permeable instead of solid dikes, was adopted in 1881; the plan being "to make the improvement continuous, working downstream from St. Louis, by reclaiming land and building up new banks, thus reducing the river to the approximately uniform width of about 2,500 feet. It is proposed by this means to secure a minimum depth of 8 feet. The depth is now liable to become as little as 4 feet in some places and less than 8 feet in every place where the width is greater than 2,500 feet. Alluvial banks are to be protected from erosion. This general statement of the proposed application of the appropriation is as specific as the nature of the case will admit of. The changeable character of the river renders it impracticable to give in advance the exact localities where works will be required." (Annual Report, Chief of Engineers, 1882, p. 1605.) The estimated cost of the improvement, as revised in 1883, was \$16,397,500.

5. By the earlier appropriation acts, the 22-mile stretch of river between the mouths of the Missouri and Illinois rivers was included in the St. Louis district, 1872 to 1890, and in the Rock Island district after 1891. Acts between 1875 and 1905 directed certain expendi-



9. The existing project for this part of the Mississippi is to contract the river to a width of about 2,500 feet, reclaiming land and building up the necessary artificial banks to create a channel 8 feet deep and 200 feet wide with increased width where alignment is unfavorable, St. Louis to mouth of Ohio River, and a channel 6 feet deep, St. Louis to mouth of Missouri River; these channel dimensions to be obtained by dredging where necessary to supplement or in the absence of the requisite works of contraction.

#### PROGRESS OF WORK

10. The interruptions to the work of contraction, due to reliance upon dredging, meager appropriations, or other reasons, have resulted in but one-third of the necessary works being completed. The scant appropriations during the war years did not even meet the needs of seasonal repair. Since 1910, when the project of 1881 was reverted to, and up to and including the fiscal year 1925 only \$2,592,920 were expended for new work.

#### CONDITION OF WORK

11. The works of contraction and bank revetment now completed are rendering real service. The heaviest injuries to completed works have been due to unprotected structures left isolated by the interruption of work on supporting and contiguous structures. Ordinary seasonal deterioration is not heavy. In the vicinity of St. Louis the effect of continuous works is most evident. The obvious benefits in thus creating an excellent channel for navigation in this instance indicate the value of completed works. The works elsewhere are of much shorter length, and although their value is not so obvious as that of the structures noted, they have given positive benefits.

12. Dredging has been resorted to in cutting through river bars during the navigation season. The characteristic configuration of the bed of a river such as the middle Mississippi at low water makes the uninterrupted maintenance of a depth greater than the natural depth quite difficult, especially in stretches only partially or not at all improved. With slowly decreasing discharge of river, bars often will cut out naturally with drop in river stage and so maintain the present project depth. It is impracticable to maintain a dredging fleet sufficient in number of dredges to safeguard the required depth at each bar. The necessity frequently arises, in a rapidly falling river, of dredging a bar only after it has become obstructive to the 8-foot depth. The intermittency of full project dimensions when using dredges to increase the natural depth of a river is important in estimating the value of such a method of maintaining specified depths.



Committee on  
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of that basin  
infall. Data  
wing table:

Station	Miles from Gulf of Mexico	Tributary entering above station	Drainage area down to station Square miles	Elevation		Average fall per mile, low water	Widths		Depth		Volumes (M cubic feet per second)	
				High water	Low water		Bank full	Low water	Natural	Project	High water	Low water
St. Paul, Minn.	1,937	Minnesota	35,800	703.0	681.6	0.391	800	360	Feet	Feet	117	1
Muscatine, Iowa	1,547	Wisconsin	98,400	550.3	529.0	0.365	2,400	1,800	2 1/2	6	289	22
Grafton, Ill.	1,297	Illinois	170,000	435.8	402.8	0.669	3,000	2,700	3	6	366	25
St. Louis, Mo.	1,258	Missouri	699,000	421.1	376.7	0.669	2,000	1,500	3	6	1,146	24
Mouth of Ohio	1,078	Ohio	916,600	325.1	269.4	0.656	3,700	2,550	3 1/2	8	2,015	71
Helen, Ark.	774	St. Francis	938,300	197.0	138.8	0.430	3,900	2,150	4 1/2	9	2,041	88
Vicksburg, Miss.	479	Arkansas	1,136,300	101.0	430.7	0.336	3,300	2,700	4 1/2	6	1,826	97
New Orleans, La.	108	Red	1,238,200	21.1	-1.7	0.112	2,140	2,050	4 1/2	9	1,358	135

1 Observed maximum and minima.  
2 Discharge measured at Columbus, Ky., 20 miles below mouth of Ohio River.  
3 Maximum measured discharge of Mississippi (Mississippi, Atchafalaya, and crevasses) 2,300,000 cubic feet per second.  
4 Maximum range in stage of entire Mississippi River system, 69.1 feet, Ohio River, Cincinnati, Ohio.

of water-borne silt into this portion of the Mississippi. Assuming that the middle Mississippi is so formed physically that this silt is now passed to the Mississippi at Cairo without change in quantity, the design of works of improvement must consider deeply the retention of this characteristic capacity of the stream.

22. The energy which keeps this water in motion and creates the velocities that can retain and move on this burden of silt is derived from slope. Works of contraction must be such as not to change violently the natural cross-sectional areas and velocities. If contraction works of improvement create a section that is too narrow, excessive velocities occur and the stream bed is eroded. A drop in water surface and in slope is therefore to be expected with too great contraction. Such drops in low-water surface have already been noted locally upon the Missouri and in this portion of the Mississippi. The following detailed study of the Mississippi River, in the vicinity of St. Louis, was made by Assistant Engineer William M. Penniman.

#### ST. LOUIS HARBOR

23. Improvement has probably changed this section of the Mississippi River more than any other part of equal extent; the formerly broad, shallow stream having here been changed to one comparatively narrow and deep. In 1837, when Robert E. Lee commenced the improvement in this part of the river, its flood width was 6 miles and average width between banks fully 4,000 feet. The present bank-full width at Pittsburg Dike (mile 1.1) and Davis Street (mile 7.5) is only 1,500 feet, and the flood width at bridges is about 2,000 feet. Bank-full and low-water widths are generally 2,000 feet and 1,500 feet, respectively, as fixed by established harbor lines. The minimum navigable depth was originally  $3\frac{1}{2}$  to 4 feet; now, for a distance of 13 miles below the Merchants Bridge it is 10 feet, and this distance includes a stretch of 5 miles ( $3\frac{1}{2}$  to  $8\frac{1}{2}$  miles below Eads Bridge) where it is 14 feet.

24. Although local navigation has in general benefited by this change, serious objections to such great contraction of the river, a contraction greatly increased in effect by the piers and abutments of four bridges, have long been known. The objectionable results from this unduly severe contraction of the river are:

- (a) Local lowering of the low-water plane.
- (b) Increased slope at low stages below Chain of Rocks (7 miles above the severe contraction), and increasing tendencies in the stretch of increased slope toward the formation of rapids obstructive to navigation.
- (c) Reduced navigable depth over the Chain of Rocks.
- (d) Local raising of the flood plane.
- (e) Great increase in velocity and in erosion of river bed at high and flood stages.
- (f) Production of depths greater than are necessary.

25. At St. Louis the stage of extreme low water has always occurred during abnormally cold winters when the stream was "gorged" or blocked with ice and had very little flow. Such lowest low water,



29. "Standard low water" of 1881, "low-water plane" for district operations, and "low water for navigation" are practically synonymous terms; and "low water" is hereby defined as the surface plane of the low-water volume of 40,000 cubic feet per second at St. Louis, approximating gauge heights and elevations (sea level) as follows:

Station	River distance	Gauge height	Elevation	Fall per mile	Remarks
	Miles	Feet	Feet	Feet	
Chain of Rocks.....	10.4	75.0	388.9	-----	Cross section, partly stable.
Eads Bridge.....	.0				
Market Street, St. Louis.....	.4	-2.0	377.8	1.03	Changeable cross section.
Grays Point.....	133.7	4.0	304.8	.55	Stable cross section.
Commerce.....	140.5	2.0	303.5	.19	Do.
Mouth of Ohio River.....	180.0	-----	274.0	.75	Elevation corresponds to 4 feet, Cairo gauge, Ohio River, 2¼ miles above mouth.

30. It is to be noted that the above defined low water is the natural minimum flow during the season of navigation, and includes no "added volume" or diversion of waters from Lake Michigan. An increment of 8,000 cubic feet per second will raise the low-water plane at St. Louis about 1 foot and, because of rise in river bottom with rise in stage, characteristic of the middle Mississippi, will increase the navigable depth about one-half foot.

31. The plane of low water over the Chain of Rocks has lowered about 2 feet because of the increased fall (par. 33) immediately below the higher parts of the rock underlying the channel; further increase in fall will cause further lowering of water surface and reduction of depth over the rock. An estimate made in 1910 for an 8-foot channel, St. Louis to mouth of Illinois River, contained an item for rock excavation, 138,000 cubic yards, at Chain of Rocks. (See H. Doc. No. 762, 63d Cong., 2d sess., p. 110.) This estimate was for the short stretch of river (miles 10 to 10.7) in the vicinity of the old intake tower and was derived from a contour map of the bedrock as determined from a large number of borings by the St. Louis Water Department in 1889. In 1912, when the new intake tower was located, additional borings eastwardly from the towers indicated that the bedrock there was not at all obstructive to 9-foot navigation. This is confirmed by the accompanying map (Pl. I) and profile (Pl. III) which show an excellent channel down to mile 9½.

32. The higher portion of the 1866-1881 discharge curve has been connected by broken line with the estimated volume (1,350,000 cubic feet per second) for the flood of 1844, extreme high water, at its true gauge height, 41.3 feet. This same volume at a newly estimated gauge height of 46½ feet for extreme high water has been similarly connected with the higher portion of the second curve which is well determined by the flood observations at Chester and Thebes. It is reported that at the Merchants Bridge the flood of 1892 swept out a 25-foot deposit of alluvium, removing it to bedrock. The flood of 1903, 38 feet gauge, was normally 6 feet lower than the flood of 1844, but, at a point one-half mile above the Merchants Bridge, was only 6 inches lower than an authentic mark for 1844. Assuming that extreme high water will now pass the Eads Bridge at a gauge

will not only have its resultant effect on any of or all the others, and as these others in turn may then react on the feature originally chosen for consideration, a brief summation of these elements is pertinent.

(a) Material of river bed varies from the extreme of solid ledge rock to that of the finest silt. Deposits of alluvium are neither horizontally nor vertically uniform.

(b) Discharge is determined mainly by the upper Mississippi-Missouri flow in the ratio of 54 to 46 for mean discharge, with tributary local drainage as a minor factor. Volume of extreme high water is more than fifty times the observed minimum flow. At times high stages in the Ohio at its mouth tend strongly to retard the flow of the middle Mississippi.

(c) Surface slope of the river section as a whole is determined by the relative stages at the Missouri-Mississippi and the Ohio-Mississippi confluences. There are many departures from this general or mean slope. The greatest local variations in low-water slope occur in the alluvial stretches where bed and banks are unstable, and bars which act as temporary dams are constantly changing in height and position. Fairly constant low-water slopes, much gentler than mean slope, are maintained wherever banks are permanent or thoroughly stable and widths are not excessive; and in the adjacent stretches, where river is wider and bank alignment and bar position change but little, such slopes are steeper than mean slope.

(d) Silt content varies principally with the stage of the Missouri River, the upper Mississippi supplying but little silt. Except in the case of a cut-off or extensive local erosion of bed and banks, the amount of silt furnished by the middle Mississippi itself is comparatively small.

36. If any of the above-described elements could be made either a definite fixed factor, or a variable with a definitely known variation, the problem of regulation would be simplified to an extent depending on the relative influence of such factor in creating the varying conditions which are characteristic of this section of the river.

37. The most difficult work in regulation will be to accomplish the fixation of the stream bed, by that term including bottom and banks, and so to fix it with definite thalweg, varying but little for the various stages, as to obviate the irregular filling of the channel with a rising river, and to force the stream flow to cut its own channel in predetermined places on falling stages.

#### CROSS WEIRS

38. Cross weirs or sill dams have been proposed for the middle Mississippi, to hold cross sections at certain selected localities to desired dimensions and grade so that low-water plane, despite bed scour, may always be maintained at the same gauge height. The low-water flow might thus be confined in a section 500 feet wide by 18 feet deep. Objections to such severe narrowing, however, are:

(a) The rolls and eddies that would occur over and below the weirs and the strong tendency toward much greater depths below them.

(b) The loss of natural cross section for low-water volume, causing natural surface planes for greater volumes to be raised, probably 3 to 5 feet for mean to bank-full volumes; and

(c) The number of such weirs required, probably exceeding the number of natural bars that may become obstructive to 8-foot navi-



cross weir might be followed with the need for a number of additional cross weirs to maintain the project depth over the weir first constructed. The tentative depth of the cross weir below the low-water plane,  $9\frac{1}{2}$  feet, is so slightly in excess of the required depth that local variations in the low-water plane in the portion of river above or below the weir, if such surface plane is not also supported by cross weirs, might easily cause encroachment upon the project depth over the weir itself. Indeed, any project for the use of cross weirs in improving the middle Mississippi could easily be extended to supporting the entire surface slope upon a number of such weirs.

#### DAMS

44. Properly designed contraction works must make but little change in the existing river velocities. The only methods now known by which contraction works could create navigable depths greatly increasing those of the present project would be by decreasing the slope of the river by the use of fixed or movable dams. Nature of foundation, extent of silt carried, and excessive cost force leaving such structures out of consideration at this time. At the same time, sill dams, or submerged weirs, distributed at frequent intervals along the river to hold the slope approximately as at present, are only recommended as a means of supporting the surface slope in exceptional instances. As permanent works of improvement are extended on the Missouri River, the amount of silt brought into the Mississippi should decrease. A change in the silt content of the Missouri, and consequently in this portion of the Mississippi, and demands for increased depth or additional contraction create new conditions to which adjustment can only be made by taking out the excess slope by fixed or movable dams. Decreased amount of silt carried, or advance in engineering art, and the increased commercial development of the Mississippi Valley in the future may make the construction of either fixed or movable dams desirable.

#### METHODS OF IMPROVEMENT

45. Improvement of this part of the Mississippi has been carried on by contracting the stream and protecting its banks, which has accomplished partial regulation, and by dredging. The method of contraction was the building up of new banks, or accretions, by means of permeable dikes or wing dams. Revetments were used to protect both natural and artificial alluvial banks from erosion. Works executed in this way, if properly designed, are a permanent investment in the river. An inspection of the various works, some of them placed in 1838, impresses the observer that practically all have rendered good service and have improved the river. In some cases structures have been destroyed, but almost always because requisite maintenance was not given them, or because the structures were left isolated by postponing the installation of necessary contiguous and supporting works. As before stated, any change in the general regimen of the river to obtain greater depth must not reduce the velocity below that necessary to carry through this section of the river the great burden of silt brought into it by the Missouri; excessive velocity that would erode the stream bed, reduce the slope, and create

49. To more closely observe the surface slope of the middle Mississippi, gauges at about 10-mile intervals below St. Louis were read in 1925, and daily readings are now being taken. This precaution will early detect any significant change of surface slope during or following the construction of the proposed regulating works.

50. It would be consistent with the science of hydraulics to artificially flatten the slope through each portion of the river contracted. Works of contraction could then be designed with the interrelated slope, volume, and mean depth to give any desired depth of channel for navigation. The cost of the structures—weirs, fixed or movable dams—with certain reservations as to the stability of the latter, to create flatter slopes, militates against consideration of these structures. There is called for, then, the design of contraction works such as to create the depths at present necessary for navigation and yet not to cause excessive erosion.

#### PROPOSED REGULATING WORKS

51. In accordance with the above principles and based upon the extensive data and experience had upon the middle Mississippi, the design of the works of contraction required is next taken up.

52. The section adopted is one that meets the demand for a stabilized steamer channel and yet does not contract too sharply the natural widths of the river. The effects of the existing works of contraction, as well as the results of river gaugings, were made use of in determining the required contraction. The section chosen represents what may be termed a "gentle contraction."

53. Using all available data, a compilation was made of the cross sections of the river existing at various stages. The following table summarizes the result of this compilation. (Also see Sheet No. 2 of maps.)

TABLE I

Subdivision of river	Length	Low water		Mean stage		Bank full	
		Average width	Average depth	Average width	Average depth	Average width	Average depth
St. Louis (Market Street) to River des Peres.....	Miles 7.6	Feet 1,700	Feet 11.5	Feet 2,205	Feet 19.9	Feet 2,755	Feet 31.0
River des Peres to Grays Point.....	125.7	1,940	10.1	3,235	15.1	4,635	23.2
Grays Point to Commerce.....	6.9	2,085	12.9	2,720	19.2	3,005	30.3
Commerce to Commercial Point.....	7.2	2,585	7.8	4,550	12.6	6,070	20.8
Commercial Point to Ohio River.....	32.2	1,900	8.3	3,435	13.9	4,735	24.2

54. Omitting the subdivision through St. Louis Harbor and the gorge near Commerce, in both of which subdivisions no change in the existing river cross section is practicable or desirable, there are seen to be three subdivisions of the river remaining, each demanding a cross-section standard within the subdivision but varying somewhat between subdivisions. The three subdivisions are: First, St. Louis to Grays Point; second, Commerce to Commercial Point; and third, Commercial Point to Cairo.

55. Supported by the above compilation, and the considerable experience had in this district with contraction works, a cross sec-



charge and in the absence of traffic requiring the full dimensions of the now proposed channel should be restricted to the needs of traffic already on the river. The present channel, project depth of 8 feet and width of 200 feet, has developed a substantial traffic with boats and barges adapted to such channel; these dimensions therefore should be maintained during any improvement for a channel of larger dimensions. In the absence of contraction works, extensive dredging will be necessary in the future, as it has been in the past, to maintain this channel.

60. The following extract from report by Col. O. H. Ernst, Corps of Engineers, August 10, 1903, when the 1903 report of the Board of Engineers was under preparation, is thought to be as pertinent to the matter to-day as when written:

A dredged channel which does not maintain itself is a very precarious foundation for trade. There is probably no place in the world where a dredged channel will have a briefer existence than in the uncontrolled part of the Mississippi River below the Missouri. \* \* \* the cost \* \* \* would certainly be large, and as it must be continuous and perpetual there is always the danger of that effort may be relaxed. This menace will, in my judgment, prevent a very extensive use of the deepened channel. \* \* \* dredging \* \* \* has what seems to me the fatal defect of being dependent upon never-ending effort. It is a temporary improvement adopted from compulsion and not from choice. \* \* \* The plans and methods of construction introduced and developed under my direction between 1879 and 1886 have proved entirely successful. \* \* \* To abandon them now for dredging is to abandon a certainty for an uncertainty.

61. The basic resolution of the Committee on Rivers and Harbors contains the language "with sufficient width of said channel around the bends in said river to afford convenient passage for tows of barges for use upon the Mississippi River." The main difficulty of handling large tows is due to the many sharp bends with strong cross currents in the low-water channel. The regulating works proposed aim at smooth easy curves for stream flow and navigation, and with compact cross section more uniform currents. In the absence of completed works it is impracticable to lay down any definite width necessary at bends in the river to facilitate the handling of large tows. Both in the construction of contracting works and in the performance of dredging, effort should be continued to avoid sharp turns in the steamer channel. The movement of bars often leaves a reef in such position that, with adverse currents and sharp change in direction of channel, it becomes practically impossible to swing a large tow about the reef without grounding, even though a channel of full project depth and width exists. The expedient is then forced in such instances of cutting down the reef by dredging and thus increasing the project width. Even with the regulating works completed, such emergency dredging will no doubt be occasionally required as in the past, although less frequently.

62. Until the regulating works below St. Louis are completed, dredging should be done to maintain a low-water channel 8 feet deep and 200 feet wide with sufficient width at bends to avoid the double-tripping of barge-tows accommodated by straight reaches; after the regulating works are completed, dredging should be done to the extent necessary to create a low-water channel 9 feet deep and 300 feet wide with similar additional width in bends for barge-tows; and it should also be provided in authorizing such channel that dredging to this maximum extent will be done only when necessary to meet the needs of the actual navigation then existing and that otherwise the aforesaid 8-foot channel will be maintained.

deterioration and should not extend above extreme low water which is 3 to 4 feet below the low water defined in paragraph 29. Hence maintaining the elevation of the low water discharge and preventing a drop in its plane is a desideratum in practical regulation.

## COST

68. The detailed location of regulating works required was made at the close of the working season of 1924. A further study was made recently of these proposed structures and the priority of the various proposed structures is suggested. Proposed structures are then presented in three classes of priority as follows:

A (red). Structures required now (1925) to protect caving banks and to remove shoals in the channel.

B (blue). Structures required in near or immediate future to complete regulation of river.

C (green). Structures required, but not immediately, to complete regulation of river.

The structures proposed in each class of priority are shown in the stated colors on separate inclosure.

69. A summary of the works proposed separated in the above priorities follows:

Priority	Linear feet		Cost		
	Hurdles	Revet-ments	Hurdles	Revet-ments	Total
A.....	120,400	145,770	\$4,816,000	\$4,373,100	\$9,189,100
B.....	152,760	81,260	6,110,400	2,437,800	8,548,200
C.....	78,320	199,200	3,132,800	4,518,800	7,651,600
Total.....					25,388,900

70. The total cost to complete the works listed under each priority, with that of necessary additions to present plant for the expeditious performance of work is, then:

Priority A.....	\$9,189,100
New plant.....	2,000,000
Total priority A.....	11,189,100
Priority B.....	8,548,200
Total priorities A and B.....	19,737,300
Priority C.....	7,651,600
Total project.....	27,388,900
Contingencies.....	3,611,100
Total cost.....	31,000,000

71. This involves an additional authorization for new work as follows:

Estimate for new work 1910.....	\$21,000,000
Less new work performed (to date).....	3,000,000
Balance.....	18,000,000
Increase in estimate, required to complete works.....	13,000,000
Total.....	31,000,000



Item 4. Invisible income from lowered freight rates..... Not estimated.

The railroad freight tariff in the lower Mississippi at present is somewhat lower in directions along the Mississippi River than in directions away from the river. This difference was very marked prior to 1922; since then many rates along the Mississippi River have been increased as much as 100 per cent. The total saving to shippers, in the past, by such depressed rail rates, has been vast and is even substantial now with the rail rates only slightly out of line along the Mississippi River. It is impossible to compute the amount of such invisible income but its extent is so great as to be notable and it is so recorded.

Item 5. Miscellaneous income..... Not estimated.

This is another type of income from a stabilized river channel which can not be reduced to value in dollars. The stabilization of the river enables large modern steam electric plants to be located, with assurance, along the river and thus serve as a foundation for industrial settlements. The various terminal facilities already existing will be safeguarded by a stabilized channel and stabilization, itself, encourages the construction of additional facilities. Recreational use of the river is encouraged and made safer by an easily followed steamer channel.

#### *Expenditures*

Item 1. Interest charges on new investment..... \$1, 240, 000

This has been computed upon the new capital investment required to complete the regulating works as presented in this review.

Item 2. Annual dredging charges..... 300, 000

The dredging performed at present is necessary to make a steamer channel 8 feet deep and 200 feet wide, and it is considered that, with the regulating works complete, a channel 9 feet deep and 300 feet wide can be maintained with no increase in present annual dredging cost.

Item 3. Maintenance charges, regulating works..... 600, 000

This estimate is based upon the past experience of this district in maintaining regulating works.

76. This comparison is naturally based upon predictions, and, as noted, slurs over some items. It is believed that the income from the improved river has been underestimated. It is worth bearing in mind that the present annual expense required on the middle Mississippi, which is \$300,000 for dredging and \$300,000 for maintenance of regulating works, can hardly be omitted in view of the large public interests of navigation and other investments involved. Present maintenance charges are still high because many isolated structures still exist unsupported along the river and deterioration is largely due to their lack of support. The additional expenditure to complete the regulating works really safeguards public expenditures already made in partially contracting the river.

#### *CONCLUSION*

77. The project presented, of contracting the middle Mississippi to fairly uniform width and stabilizing its banks, may not be the final work of molding this part of our great interior river to the demands of commerce. There are two extremes which limit possible effort upon this river: First, the present works of bank protection and contraction and the annual dredging operations might be entirely given up. This would result in a channel with a natural depth of about 4 feet and a main river shifting from time to time over the entire alluvial plain.

82. In compliance with law, it is reported that there are no questions of terminal facilities, water power, or other subjects so related to the project proposed that they may be coordinated therewith to lessen the cost and compensate the United States for expenditures made in the interests of navigation.

#### MAPS

83. There are submitted herewith the project maps in 16 sheets, scale 1:20,000, which show the works proposed, the condition of present works and numerous other features necessary to a full presentation of this review; graphical representation of the priorities cited in paragraph 68, in atlas form on reduced scale project maps; and the drawings described in paragraph 34, pertaining to the study of St. Louis Harbor.

#### RECOMMENDATIONS

84. For the improvement of Mississippi River between the mouth of Ohio River and the northern boundary of the city of St. Louis, it is recommended:

(a) That the regulating works of contraction and revetment be continued and completed.

(b) That prior to completion of regulating works, dredging be continued to maintain the present project channel, 8 feet deep and 200 feet wide with requisite increased width at bends.

(c) That after completion of regulating works, dredging be continued, as needed, to maintain a channel 9 feet deep and 300 feet wide with requisite increased width at bends: *Provided*, That dredging of channels deeper than 8 feet and wider than 200 feet be authorized only when the needs of navigation then existing are not adequately met by such 8-foot channel.

(d) That all regulating works between the mouth of Ohio River and St. Louis be completed before new works above Merchants Bridge are undertaken.

(e) That a new capital expenditure of \$31,000,000 (increase of \$13,000,000 over preceding estimate, 1910) be made for the improvement, covering regulating works and construction plant.

JOHN C. GOTWALS,  
Major, Corps of Engineers,  
District Engineer.

[First indorsement]

OFFICE DIVISION ENGINEER, WESTERN DIVISION,  
St. Louis, Mo., June 24, 1926.

To: The Chief of Engineers, United States Army, Washington, D. C.  
Subject: Review of project for improvement of Mississippi River between mouth of Ohio River and northern boundary of the city of St. Louis, Mo.

1. The recommendations of the district engineer are concurred in.
2. This report is the result of very thorough study based on many years' experience of the St. Louis engineer office in the regulation of the middle Mississippi, and the conclusions are well worth acceptance and thoughtful application to the problem of its improvement.

CHAS. L. POTTER,  
Colonel, Corps of Engineers.