1873

all probable contingencies in completing the work, the officer in charge asks for an appropriation of $112,000.

Amount available July 1, 1872	$130,197 43
Amount appropriated March 3, 1873	50,000 00
Amount expended during fiscal year ending June 30, 1873	126,162 19
Amount available July 1, 1873	54,035 24
Amount required for the fiscal year ending June 30, 1875	112,000 00

(See Appendixes I 6 and I 7.)

5. *Improvement of Illinois River.*—No appropriation having been made since 1870 for this work until March 3, 1873, operations were confined during the fiscal year to closing the work under old appropriation and preparing a project for resuming work under that recently made. This last appropriation will be applied to payment for lock-bottom and foundation at Copperas Creek, and about one-fifth will be reserved for expenses of supervising work, and particularly for such dredging as will best relieve the immediate wants of the navigation.

Amount available July 1, 1872	$12,548 53
Amount appropriated by act of March 3, 1873	100,000 00
Amount expended during fiscal year ending June 30, 1873	13,829 34
Amount available July 1, 1873	98,719 19
Amount required for fiscal year ending June 30, 1875	150,000 00

(See Appendix I 8.)

EXAMINATIONS AND SURVEYS FOR IMPROVEMENT.

Colonel Macomb was charged with and has completed a survey of the Minnesota River above the mouth of Yellow Medicine, to comply with provisions of the act of June 10, 1872. (See Appendix I 10.)

IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OF THE OHIO—OF OSAGE AND CURRENT RIVERS, MISSOURI—OF LITTLE MISSOURI RIVER, ARKANSAS—OUACHITA RIVER, IN ARKANSAS AND LOUISIANA, AND OF YAZOO RIVER, MISSISSIPPI.

Officers in charge, Lieut. Col. W. F. Raynolds, Corps of Engineers, to January 1, 1873, since which time Col. J. H. Simpson, Corps of Engineers, having under his immediate orders Capt. C. J. Allen, Corps of Engineers.

Colonel Simpson was relieved of the charge of the improvement of the Ouachita and Yazoo Rivers May 9, 1873, and those works turned over to Capt. W. H. H. Benyaurd, Corps of Engineers. For this officer's report of operations to end of fiscal year June 30, 1873, see Appendix K 12.

1. *Improvement of the Mississippi River between the Illinois and Missouri Rivers.*—The work under this head has consisted in the closing of the slough behind Ellis Island, opposite Alton, by a dam raised to the height of 6 feet above low water, constructed of brush and stone, and designed to throw that portion of the low-water discharge thus intercepted into the main channel in front of Alton landing. The materials were furnished by contract. The estimate for a low dam and for the necessary protection of the head of Ellis Island against "wash" is $40,000.

Amount appropriated June 10, 1872	$25,000 00
Amount expended during fiscal year ending June 30, 1873	21,978 18
Amount on hand July 1, 1873	3,021 82
Amount required for fiscal year ending June 30, 1875	15,000 00

(See Appendix K 1.)

2. *Improvement of the Mississippi River from the Missouri River to the Ohio River.*—The act of Congress approved March 3, 1873, appropriated the sum of $200,000 for the improvement of the Mississippi River within the above-named limits. Of this sum $50,000 was allotted to the works in the immediate vicinity of Saint Louis, which had been commenced under the appropriation made June 10, 1872, of $100,000. The $150,000 remaining after the allotment of the $50,000 it is proposed to expend in the improvement at Horse-Tail Bar, below Saint Louis.

A survey of the river from Kimswick to Cairo was made last season, which, in connection with previous surveys, reaching from Kimswick up to the Missouri, would, it was thought, enable projects to be submitted, with estimates of cost for the improvement of the stream. The survey from Kimswick down was not as complete as was desired, but enough is known from it and from the examinations made this season to demonstrate the existence of numerous and formidable obstructions to navigation. The officer in charge estimates that the sum of $600,000 can be profitably expended for this improvement during the year ending June 30, 1875, and in this sum includes the balance necessary for completing the work in the vicinity of Saint Louis Harbor. He also recommends an appropriation of $50,000 for further surveys between the Illinois and Ohio Rivers. The estimate for this sum, however, is embraced in his report on the examination and survey of the Mississippi River from the Missouri River to the Ohio River.

Amount appropriated March 3, 1373	$200,000 00
Amount expended during the fiscal year ending June 30, 1873	1,450 00
Amount available July 1, 1873	198,550 00
Amount required for fiscal year ending June 30, 1875, for improvement of the Mississippi River from the Missouri to the Ohio River	600,000 00

(See Appendix K 2.

3. *Improvement of the Mississippi River from the Missouri to the Meramec.*—This work has consisted in the protection of a portion of Sawyer Bend, above the city of Saint Louis, and the raising and extension of the long dike in Venice Bend, (harbor of Saint Louis.) Fourteen hundred and seventy-five linear feet of Sawyer Bend have been protected, of which 1,118 feet consist of a longitudinal retaining-wall with bank sloped and reveted; for the remaining 357 feet cross-dikes abutting against the longitudinal dike have been used. The materials, consisting of brush, stone, and piles, were furnished by contract.

In the Venice Bend about 480 linear feet of the long dike were raised 7 feet and the dike extended about 130 feet. Cold weather the latter part of November put a stop to operations. The materials of the dike were brush, stone, and piles, and were furnished by contract. It is proposed to continue the work during the present season.

Amount appropriated June 10, 1872	$100,000 00
Amount expended during the fiscal year ending June 30, 1873	42,018 67
Amount of per centage due to contractors at close of fiscal year ending June 30, 1873	2,712 35
Amount available July 1, 1873	55,268 98
Amount allotted from appropriation of March 3, 1873, for improvement of Mississippi River from the Missouri to the Ohio	50,000 00
Amount of total available July 1, 1873	105,268 98
Amount required in addition to the above for the fiscal year ending June 30, 1875	189,535 52

Which sum is included in the estimate for the improvement of the Mississippi River from the Missouri to the Ohio, given in the report of that section.

(See Appendix K 3.)

K 2.

IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF MISSOURI AND OHIO RIVERS.

A survey from Kimmswick (about twenty miles below Saint Louis) to Cairo was undertaken during last season for the purpose of developing the condition and needs of this portion of the river in the interests of navigation and the conduct of the survey given to Mr. Clement Smith, whose report, together with that of my predecessor upon the same, were duly forwarded to the Department. It was thought that the previous surveys above Kimmswick, in connection with those by Mr. Smith, would be sufficient.

My predecessor's estimate of funds necessary to carry out this improvement was $2,996,044, which is certainly not in excess of what would be necessary.

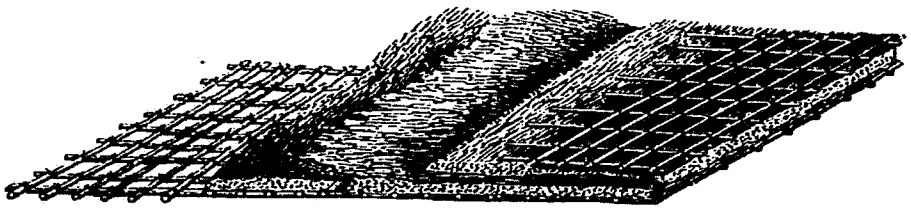
The last Congress appropriated, by act approved March 3, 1873, the sum of $200,000 for the improvement of the Mississippi River between the Missouri and the Ohio. It was recommended from this office, April 28, and approved by the Department May 3, that $50,000 of this sum be allotted for the further protection of Sawyer Bend, and $150,000 for the improvement of the river at the locality known as Horsetail Bar, and as the plans for the prosecution of this latter work during the coming season involved the necessity of constructing dikes and dams, I was authorized to proceed at once with the preliminary steps of advertising for proposals for material and labor.

Bids were opened on the 26th of June, and contract for both sections awarded to Mr. Thomas Hackett, he being the lowest, as per abstract appended hereto.

Preliminary examinations and surveys to enable the location of the works to be defined were commenced in March and continued until June, when the maps were projected, and plans having been drawn up the project was submitted to the Chief of Engineers for his approval on the 9th of July and approved the 22d of the same month.

H.

ISOMETRICAL PLAN SHOWING DETAILS OF CONSTRUCTION OF BRUSH RAFTS TO BE USED IN THE IMPROVEMENT OF THE MISSISSIPPI RIVER



Scale. 20 ft-1 inch

This project involved the construction of four jetties at certain points approximately indicated upon the map submitted therewith, for the

contraction of the water-way, and a dam to close Carroll's Island slough, and recommended that work be commenced this season upon the dam and jetties 1, 3, and 4.

An additional feature is proposed to be introduced in the construction of dams and jetties, when needed, viz, the use of brush rafts or mattresses, a sketch of which accompanies this report. (See sketch H.)

The Board of Engineers convened here in February by Special Orders No. 20, Headquarters Corps of Engineers, dated February 7, 1872, recommended that the sum of $30,000 be appropriated for a survey of the localities, when the general navigation of the river requires an increase of depth at low water, between the Missouri and the mouth of the Ohio, and added that it was not improbable that an accurate survey of the whole distance would become necessary, when an additional appropriation would be needed.

The sum of $22,584.79 was expended, from an allotment made from the general appropriation for examinations and surveys, &c., in making this survey, but the deficiencies of the survey made last fall are so apparent that an additional sum is necessary with which to carry it on.

Previous to the fiscal year just closed, a large amount of data had been collected pertaining to the portion of the river between the Missouri and the Meramec.

Surveys have been made at various times, which, if collected, would cast much light upon the changes which have taken place; but in making such camparisons we meet, at the outset, the difficulty, that for want of common points no exact comparison is possible, and we fail to derive the information which the surveys ought to give, and are thrown back upon uncertain traditions when we should have positive facts. To obviate this difficulty in future, a triangulation of the river has been undertaken, to fix definitely the course, main features of the river as it now is, and to establish a series of permanent points to which all surveys can be referred. The party for this work is now in the field, having commenced the latter part of May.

The funds required, in the absence of a special appropriation, are taken from the general fund for improvement.

The triangulation in progress will have great value in the future, but cannot afford all that is requisite, as it includes only the river-bed, and many of its points must be lost as the river changes.

A triangulation of the valley proper, from bluff to bluff, is very desirable, and special appropriations to execute it are earnestly recommended. The estimate for this latter survey I give in my report of the examination and survey of the river, herewith submitted.

The party spoken of commenced the work of triangulation of the river, from bank to bank, between this point and Cairo, after the conclusion of its special examinations at Horsetail Bar.

It is my design, with your approval, to cause special examinations to be made, when the low-water season sets in, at such points as first need improvement, below Horsetail Bar.

Basing my opinion upon reports of previous examinations, I am of the opinion that the sum of $600,000 can be profitably expended during the year ending June 30, 1875, between Missouri and the Ohio, including in this the work at Sawyer Bend, Saint Louis Harbor, and further work, if necessary, at Horsetail Bar.

In prosecuting the works of improvement, surveys, &c., the necessity for the possession of a light, swift steamer, with accommodations for engineers, surveyors, inspectors, draughtsmen, &c., is daily rendered apparent, and will be much greater another year, as our work is carried

further from Saint Louis. The cost of such a steamer as is needed would be not less than $30,000.

Assuming that in answer to the demands of the commercial and producing interests the improvement of the navigation of the Mississippi is to be undertaken, it would be advisable on the score of economy to adopt the policy that the United States should own the principal working appliances which must be used, such as pile-drivers, dredges, and possibly barges and tow-boats for the transportion of materials. Even if the contract system is adhered to, it is found much more economical to provide the equipment, which as representing a fixed capital must be paid for either in increased prices for work or by direct purchase.

Government owning the equipment an extended competition may always be expected. In the other case the amount of fixed capital required will restrict the competition to very narrow limits, and put the work at the mercy of combinations.

The following shows the financial condition of the improvement at the close of the fiscal year, and the amount recommended for the year ending June 30, 1875:

Amount appropriated March 3, 1873	$200,000 00
Amount expended during the fiscal year ending June 30, 1873	1,450 00
Amount available July 1, 1873	198,550 00
Additional amount required for the fiscal year ending June 30, 1875, for improvement of the Mississippi River from the Missouri to the Ohio River	$600,000 00

Abstract of proposals for furnishing and delivering materials and labor and doing all the work required for the improvement of the Mississippi River, first section, opened at engineer office, U. S. A., 1122 Pine street, Saint Louis, June 26, 1873.

Names of bidders.	Loose brush, 1st grade, 1,000 cords.		Loose brush, 2d grade, 2,000 cords.		Rafted brush, 1,000 squares.		Pile-timber, 15,000 feet.		Stone for dry rip-rap, 8,000 cubic yards.		Stone for wet rip-rap, 12,000 cubic yards.		Spalls, 3,000 cubic yards.		Gravel, 3,000 cubic yards.	
	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.
Willard Johnson	$3 50	$3,500	$3 00	$6,000	$8 00	$8,000	$0 08	$1,200	$2 00	$16,000	$2 00	$24,000	$0 90	$2,700	$0 60	$1,800
Barker, Whittlesey & Co.	4 40	4,400	3 25	6,500	6 00	6,000	04	600	2 00	16,000	2 00	24,000	1 00	3,000	1 00	3,000
Thomas M. Hackett	3 00	3,000	2 40	4,800	2 80	2,800	06	900	1 50	12,000	1 40	16,800	1 50	4,500	2 50	7,500

Names of bidders.	Excavation, dry, 20,000 cubic yards.		Dredging, 600 hours.		Transportation of stone, 2,000 units.		Driving piles 6 feet, 600 piles.		Driving piles in excess of 6 feet, 1,200 feet.		Labor of men, 1,000 hours.		Labor of teams, 800 hours.		Total amount.
	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	
Willard Johnson	$0 20	$4,000	$10 00	$6,000	$0 15	$300	$0 18	$108	$0 08	$96	$0 20	$200	$0 50	$400	$74,304
Barker, Whittlesey & Co.	40	8,000	10 00	6,000	10	200	36 60	360	14 15	180	25	250	40	320	78,810
Thomas M. Hackett	20	4,000	9 00	5,400	02	40	80 2 00 4 00	1,200	20 20 30	240	25	250	50	400	63,830

Abstract of proposals for furnishing and delivering materials and labor and doing all the work required for the improvement of the Mississippi River, second section, opened at engineer office, U. S. A., 1122 Pine street, Saint Louis, June 26, 1873.

Names of bidders.	Loose brush, 1st grade, 4,000 cords.		Loose brush, 2d grade, 8,000 cords.		Rafted brush, 6,000 squares.		Pile-timber, 4,500 feet.		Stone for dry rip-rap, 8,000 cubic yards.		Stone for wet rip-rap, 8,000 cubic yards.		Spalls, 3,000 cubic yards.		Gravel, 3,000 cubic yards.	
	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.
Willard Johnson	$3 50	$14,000	$3 00	$24,000	$8 00	$48,000	$0 08	$3,600	$2 00	$16,000	$2 00	$16,000	$0 90	$2,700	$0 60	$1,800
Barker, Whittlesey & Co.	4 10	16,400	3 25	26,000	6 00	36,000	04	1,800	2 00	16,000	2 00	16,000	1 00	3,000	1 00	3,000
Thomas M. Hackett	3 00	12,000	2 05	16,400	2 45	14,700	06	2,700	1 35	10,800	1 27	10,160	1 40	4,200	2 00	6,000
S. O. Hemenway	4 95	19,800	4 95	39,600	12 00	72,000	40	18,000	1 50	12,000	1 50	12,000	1 50	4,500	1 50	4,500

Names of bidders.	Excavation, dry, 10,000 cubic yards.		Dredging, 600 hours.		Transportation of stone, 10,000 units.		Driving piles 6 feet, 1,800 piles.		Driving piles in excess of 6 feet, 4,000 feet.		Labor of men, 1,000 hours.		Labor of teams, 800 hours.		Total amount.
	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	
Willard Johnson	$0 20	$2,000	$10 00	$6,000	$0 15	$1,500	$0 18	$324	$0 08	$320	$0 20	$200	$0 50	$400	$136,844
Barker, Whittlesey & Co.	40	4,000	10 00	6,000	10	1,000	36 60	1,080	14 15	600	25	250	40	320	131,450
Thomas M. Hackett	20	2,000	9 00	5,400	02	200	80 2 50	4,500	20 25	1,000	25	250	50	400	90,710
S. O. Hemenway	193	1,975	5 00	3,000	20	2,000	4 50 80 2 25	1,440	40 26 25	800	29	290	60	480	192,385

K 3.

IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE MISSOURI AND MERAMEC RIVERS.

The work was undertaken in accordance with the recommendations contained in the report of the Board of Engineers, dated April 13, 1872, and concurred in by the Chief of Engineers. The Board recommended the protection of a portion of Sawyer Bend, and the raising an extension of the two Venice Dikes and the Long Dike within the limits of the harbor of Saint Louis.

It was decided to do the work mainly by contract, and advertisements were issued inviting proposals. Bids for furnishing and delivery of material in Sawyer and Venice Bends were opened on the 10th of September, and contract awarded to the Grafton Stone and Transportation Company, they being lowest, as may be seen by the abstract of proposals given below.

It was intended to perform all the grading necessary, by hired labor, but as the workmen of the Government would then be working under the 8-hour law and those of the contractors would not be within its provisions, it was deemed best to do this by contract also, and proposals were therefore invited for the removal of 75,000 cubic yards, more or less of earth, spreading of 3,300 squares of Macadam and other labor, as well as unclassified labor. The contract was awarded to Mr. Willard Johnson, of Fulton, N. Y., as per abstract accompanying this report, he being the lowest bidder.

The nature of the work as well as its extent for the year is given in the following, quoted from the report of Mr. R. E. McMath, principal civil assistant on this work, dated July 10, 1873:

Preliminary surveys were made during August, to determine location of lines and detail of plans.

For the work at Sawyer Bend it was decided to commence at the foot of Grand avenue, and carry the protection up stream as far as the means will allow. The use of brush in foundations to prevent the stone from sinking indefinitely in the underlying sand was thought best, though such use for this purpose and at such a place was to some extent an experiment. Before examination of the locality it had been proposed to protect the bank by a system of spur-dikes below low water, and a continuous revetment of the slope above. As that system still has its advocates it may be well to state the grounds for the preference of a continuous longitudinal dike as a foundation for the revetment.

The spur-dikes as proposed were to be 150 feet apart, 50 feet in length and 6 feet high, each spur being expected to protect three times its length, an expectation founded on experience, but not considering that these dikes would be submerged, and therefore very unlike jetties when the current sweeps around the end but does not run over.

In the case of submerged wiers, the action of the eddy below is well known to be sufficient to require an extension of the abutments down stream, and this is a similar case.

Another fallacy in the theory of spur-dikes, as suggested for this locality, is apparent on consideration of the effective length which is a horizontal line, therefore if the dike be of uniform height, resting on a slope, the expression for the effective length would be effective $L = \frac{h}{S}$ or wholly independent in the length of dike, which only can enter as a limitation, when sine slope becomes very small, showing that the theory is only applicable in cases of level bottom.

The underwater slope at Sawyer Bend was found to be about 2 horizontal to 1 perpendicular until a depth of 18 feet was reached, when it became nearly level, consequently the spur-dikes, aside from the first objection, would have to be at least 18 feet high at the outer end to make their effective length answer the conditions, and in that case the cost would exceed that of the longitudinal dike adopted.

The plan adopted was to excavate, where necessary, a trench to the depth of 8 feet below lowest water, and fill it with brush in crossed courses, the tops reaching outward as far as practicable, to form a mat to protect the base from scour; on the brush,

riprap is placed until it appears at mean low water, which was assumed at 5.6 above lowest low water, the rip-rap forming the base of the revetted slope.

After a discussion of various slopes, that of 2 horizontal to 1 perpendicular was adopted, chiefly as that furnished material for the grading better than any other.

The detail of plan is the same as for the wings of the abutments at the Alton dam.

Work was begun October 13, 1872, and except when suspended on account of ice, or delay in furnishing material, continued until June 30, 1873, when it was completed so far as is practicable at the present stage of water.

The length protected is 1,475 feet, of which 1,118 feet is revetted; the remainder is protected by cross-dikes.

The latter method was adopted as a temporary expedient to protect the work, but having proved itself a complete protection of the bank, equally efficacious and less costly than revetment, it is proposed to continue the protection by cross-dikes in future and abandon the revetment.

Of the original distance of two miles 1,475 feet are now complete; 1,450 feet has been undertaken by the board of water commissioners for the city of Saint Louis, leaving 7,635 feet to be done, towards which we have an available balance of $13,883.98 from allotment of $50,000 of appropriation by act dated June 10, 1872, and $50,000 from appropriation dated March 3, 1873.

A contract has been recently awarded to Thomas M. Hackett for continuation of the work under the late appropriation.

The balance of the former is to be relet.

VENICE BEND.

Raising and extension of Long Dike is in continuation of an old work begun by the city of Saint Louis, the old dike being 1,460 feet long and generally 6 feet above lowest water. Work was begun October 4, 1872, and progressed slowly until about one-third of the length was raised 7 feet, when the contractor ceased delivering stone, as the depth of water at the dike was insufficient for his barges.

In November an effort was made to extend the dike, but the contractor did not deliver any material until the 12th, and then a severe storm, followed by a run of heavy ice, prevented its use until the 22d, when the brush was laid upon the ice as a last resort, a dangerous experiment, but being favored by good weather the riprap was put on and the brush sunk; the section put down was 130 feet long by 30 feet wide; it being at the end of the dike, where usually the sand is scoured out in the winter to a depth of 30 feet or more, it has been exposed to a severe test of the efficiency of brush foundations. When examined in February last, after the ice ran out, it was uninjured.

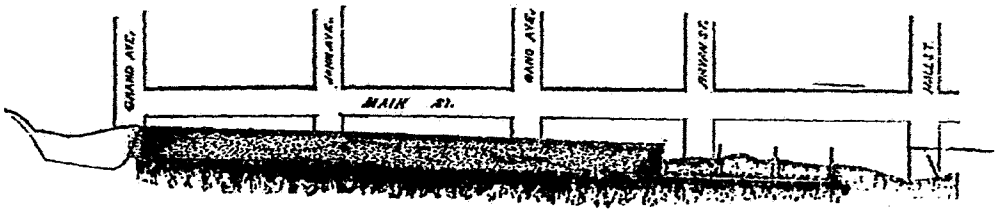
The sand accumulating at the end of the dike in high water, and scouring out at low, (a change of 20 feet being shown from August to November,) it is scarce to be regretted that we did not succeed in accomplishing more last season, as if resumed in August this year the extension will require but a fraction of the material which would have been used last fall, and the portion done is meanwhile being tested.

The extension proposed is essentially the same in plan as the Alton dam.

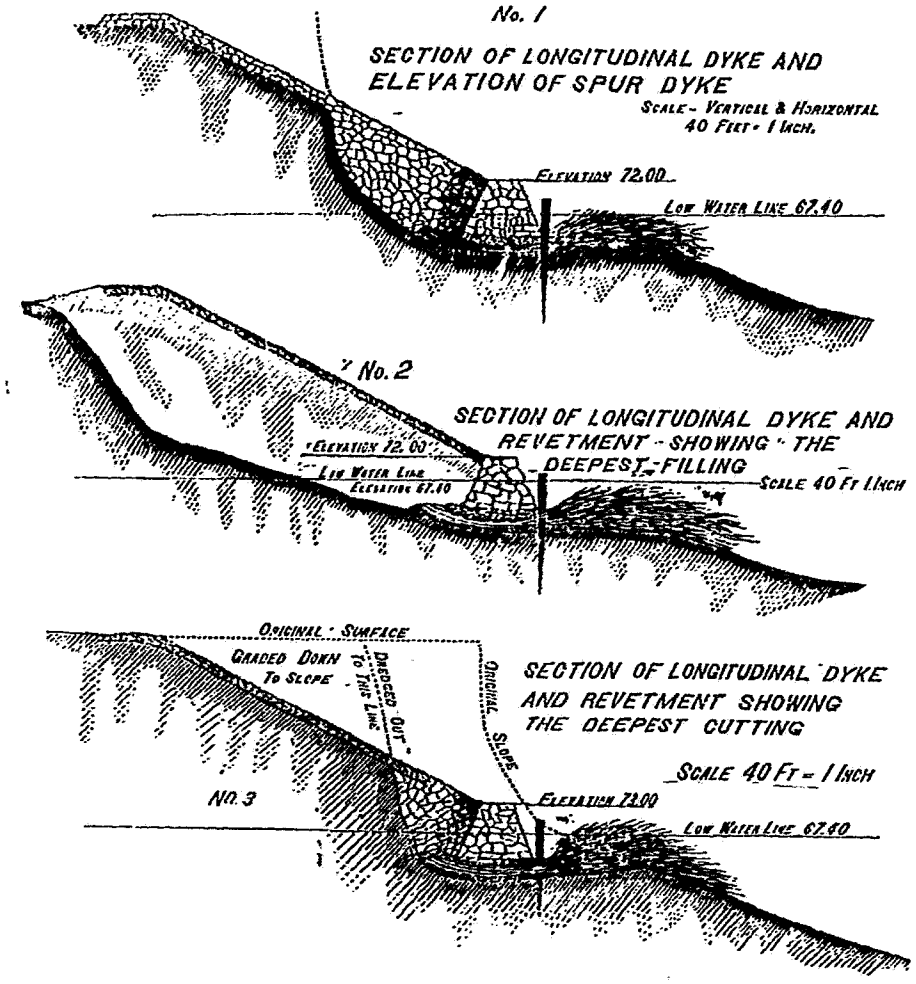
The amount expended on account of this work has been $8,615, leaving a balance of $41,385 available for further work out of the $50,000 allotted for the work at this locality.

Former contracts terminating July 1, the work is to be relet under amended specifications.

The balance just stated is all that can be profitably expended this season, and so far as I can now judge will be more than sufficient to complete the raising and extension of Long Dike.



PLAN OF IMPROVEMENT AT SAWYER BEND.



The board estimated as follows:

Protection of two miles of Sawyer Bend	$142,211 62
Extension and raising of dikes in northern harbor of Saint Louis	197,323 90
Total	339,535 52

As before mentioned, Congress appropriated the sum of $100,000 toward this by act approved June 10, 1872, and out of the appropriation by the next Congress of $200,000 for the improvement of the Mississippi River, between the Missouri and the Ohio, $50,000 were recommended to be expended in Sawyer Bend; subtracting, then, the sum of the two, viz, $150,000, from the estimate submitted by the board for this work, a deficiency of $189,535.52 exists, which can be profitably expended during the year ending June 30, 1875.

Accompanying this are two sheets, F and G, of sketches showing plan and sections of work in Sawyer Bend.

The following shows the financial condition of the work at the close of the fiscal year, and the amount recommended for the year ending June 30, 1875:

Amount appropriated June 10, 1872		$100,000 00
Amount expended during fiscal year ending June 30, 1873	$42,018 67	
Amount of percentage due to contractors at close of fiscal year ending June 30, 1873	2,712 35	
		44,731 02
Balance available July 1, 1873		55,268 98
Amount allotted from appropriation of March 3, 1873, for improvement of Mississippi River from the Missouri to the Ohio		50,000 00
Total amount available July 1, 1873		105,268 98
Amount required in addition to the above for the fiscal year ending June 30, 1875		189,535 52

Respecting the amount named in the above statement as required for the fiscal year ending June 30, 1875, I would state that this sum is embraced in the estimate of $600,000 recommended to be appropriated for the improvement of the Mississippi River from the Missouri to the Ohio, as stated in my report upon that work.

Abstract of proposals received and opened September 10, 1872, for furnishing and delivering the stone and brush required for the improvement of the Mississippi River near Saint Louis, Missouri.

Number.	Names of bidders.	Sawyer Bend.								Venice Bend.						Total.
		Brush, 1,000 cords.		Riprap, 1,000 yards.		Revetment, 12,500 yards.		Macadam, 1,100 squares.		Brush, 1st grade, 2,250 cords.		Brush, 2d grade, 2,250 cords.		Riprap, 21,000 yards.		
		Price per cord.	Amount.	Price per yard.	Amount.	Price per yard.	Amount.	Price per square.	Amount.	Price per cord.	Amount.	Price per cord.	Amount.	Price per yard.	Amount.	
1	Gottleib Egermann & Co	$6 15	$6, 150 00	$2 10	$2, 100 00	$3 25	$40, 625 00	$7 90	$8, 690 00	$7 50	$16, 875 00	$5 50	$12, 375 00	$1 95	$40, 950 00	$127, 765 00
2	H. C. Woodrow, secretary of Grafton Stone and Transportation Co.	4 95	4, 950 00	1 15	1, 150 00	1 85	23, 125 00	4 00	4, 400 00	4 45	10, 012 50	4 95	11, 137 50	1 15	24, 150 00	78, 925 00
3	Haas & Schreiber, Skrarinka & Vieths	2 10	2, 100 00	1 42	1, 420 00	1 47	18, 375 00	7 50	8, 250 00	8 00	18, 000 00	2 10	4, 725 00	1 47	30, 870 00	83, 740 00
4	Samuel L. Fisher	.....	.....	.....	.....	.....	.....	.....	.....	3 84	8, 640 00	3 64½	8, 201 25	1 69	35, 490 00	52, 331 25
5	Otis A. Turner	4 00	4, 000 00	2 00	2, 000 00	2 75	34, 375 00	10 00	11, 000 00	7 00	15, 750 00	4 00	9, 000 00	2 00	42, 000 00	118, 125 00
6	S. H. Klinger	5 00	5, 000 00	1 50	1, 500 00	1 75	21, 875 00	7 00	7, 700 00	6 00	13, 500 00	6 00	13, 500 00	1 50	31, 500 00	94, 575 00
7	Willard Johnson	2 75	2, 750 00	1 75	1, 750 00	1 95	24, 375 00	1 75	1, 925 00	2 75	6, 187 50	2 75	6, 187 50	1 75	36, 750 00	79, 925 00
8	Wells, Timberman & Co.	4 00	4, 000 00	2 25	2, 250 00	3 00	37, 500 00	8 50	9, 350 00	4 00	9, 000 00	4 00	9, 000 00	2 25	47, 250 00	118, 350 00

Abstract of proposals received and opened September 11, 1872, for grading and other work required for the protection of Sawyer Bend, near Saint Louis, Missouri

Number.	Names of bidders.	Grading, 75,000 yards.		Covering revetment with Macadam, 3,300 yards.		Total.	Remarks.
		Price per cub. yard.	Amount.	Price per square.	Amount.		
1	Gottleib Egermann and Robert McAllister	$0 27½	$20, 625 00	$0 89½	$2, 953 50	$23, 578 50	Bid not addressed; guarantors not certified to.
2	William O. Hemenway	0 19½	14, 812 50	1 43	4, 719 00	19, 531 50	Signatures of guarantors not witnessed.
3	Haas & Schrieber, Skrarinka & Vieths	0 17½	13, 125 00	0 98	3, 234 00	16, 359 00	Signatures of guarantors not witnessed.
4	Thomas M. Hackett	0 17½	13, 125 00	0 55	1, 815 00	14, 940 00	Bid not addressed.
5	Michael J. Costello and Calvin C. Porter	0 19	14, 250 00	0 40	1, 320 00	15, 570 00	Bid not addressed, and signatures of guarantors not witnessed.
6	P. J. Kearey	0 19½	14, 812 50	1 25	4, 125 00	18, 937 50	Bid not addressed.
7	Peter A. O'Neil	0 19½	14, 812 50	0 34	1, 122 00	15, 934 50	Bid not addressed.
8	Howard Cook	0 22½	17, 062 50	0 60	1, 980 00	19, 042 50	Bid not addressed.
9	Willard Johnson	0 18	13, 500 00	0 10	330 00	13, 830 00	

K 8.

EXAMINATION AND SURVEY OF THE MISSISSIPPI RIVER FROM THE MISSOURI RIVER TO THE OHIO RIVER.

Under the requirements of the act of Congress approved June 10, 1872, a survey of the Mississippi River from Kimmswick to Cairo was made, during the fall of 1872, by Mr. Clement Smith, assistant engineer, and report made by him to my predecessor, who forwarded it to the Chief of Engineers December 18, 1872. The report constitutes Ex. Doc. No. 25, Forty-second Congress, third session.

The survey being found incomplete, permission was asked March 11, 1873, and obtained April 4, to renew the surveys. Accordingly a party was organized for this purpose, commencing, however, with the examination of that locality known as Horse-tail Bar. This being completed in May, the party started down the river for the purpose of carrying on the triangulation towards Cairo, and on the 30th of June had reached as far as Herculaneum Island, about twenty-eight miles below Saint Louis.

The result of the examination of Horse-tail Bar has already been given in my project for the improvement of that locality, submitted July 9, 1873, and approved by the Chief of Engineers under date of the 22d of the same month. The above survey, however, is only of the river bed, and as many of the points of reference will be lost in the changes of the bed of the river which are constantly going on, it is very important that the immediate valley of the river should be triangulated as far as it may be done from bank to bank. The value of this survey is only too evident, and as early as February, 1871, it was recommended in report of Capt. Charles J. Allen, Corps of Engineers, and also that it extend up the Missouri to the bluffs, a few miles above its mouth. The amount required for this purpose is estimated at $50,000, which I recommend may be appropriated by Congress.

The following shows the condition of the funds allotted for the above surveys from the appropriation for examinations and surveys with a view to the improvement of rivers and harbors, at the close of the fiscal year, and the amount required for the triangulation of the main valley of the Mississippi River, from the Illinois River to the Ohio River, for the year ending June 30, 1875:

Amount allotted from appropriation of June 10, 1872			$23,200 00
Amount of unexpended balance of allotment from former appropriation			1,795 59
Amount available July 1, 1872			24,995 59
Amount expended during fiscal year ending June 30, 1873:			
On account of Gasconade River—			
By Lt. Col. Raynolds	$766 30		
By Colonel Simpson	180 00		
		$946 30	
On account of Saint Francis River—			
By Lt. Col. Raynolds	722 50		
By Colonel Simpson	104 80		
		827 30	
On account of Yazoo River—			
By Colonel Simpson		345 80	
On account of consideration and report upon location, plans, &c., of bridge at Nebraska City, Nebr.—			
By Colonel Simpson		291 40	

On account of Mississippi River, from Missouri River to Ohio River—			
By Lt. Col. Raynolds	$11,523 93		
By Colonel Simpson	11,060 86		
		$22,584 79	
Total expended			$24,995 59
Amount required for the fiscal year ending June 30, 1875, for triangulation of the valley of the Mississippi River, from the Illinois River to the Ohio River			$50,000 00

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Louis, Mo., June 13, 1873.

COLONEL: I have the honor to submit the following, relative to the improvement of that portion of the Mississippi River known as Horse-tail Bar in continuation of report submitted by me on the 18th of January last.

The surveying party of Mr. McKown, owing to the unusually tempestuous weather of this spring, were delayed much longer than was anticipated, in making their examinations, deferring the completion of the maps until the present.

This locality having been described in my report referred to, I will pass on to a general discussion of the points involved in its improvement.

Looking at the subject from a purely engineering point of view, the object would be to shorten the low-water channel as little as possible, and, if allowable, on the contrary to elongate it; to proportion the discharge of water for every stage to the area of cross-section so as to secure a stable regimen and at the same time not oppose too great a velocity to ascending boats, and to lead the gravels and heavier deposits into the high-water channels, leaving the lighter material to be dealt with by the low-water volume, or, rather, leaving the low-water discharge only the lighter and more yielding material to deal with.

The interests of general navigation only require that a good stage of water be secured during the year throughout the length of the bar.

The interests of commerce at this point require, or will require, not only a navigable stage for the passage of steamers and barges throughout the length of the bar, but in addition, the same or nearly the same depth across it. I will not at present attempt to draw the line between them, leaving that for future discussion.

Accompanying this is an outline sketch of the river and both banks from Lesperance street, above the arsenal, to a point below the foot of Carroll's Island.

Horse-tail Bar may be said to be anywhere between the mouth of the Des Peres and the foot of Carroll's Island, its size and position varying from year to year, so that, generally, until the foot of the island has been passed some distance, obstructions to navigation may be looked for at low water.

In 1870 the position of the bar was, as shown in the sketch, just below the Des Peres. In 1872 it had shifted lower down and nearer to the barracks. What its exact position will be this year can only be known when the low-water season sets in. But as the entire distance from the Des Peres to the foot of Carroll's Island is subject to shoalness more or less throughout its length, constituting one of the worst obstructions to navigation below Saint Louis, the work of contracting the low-water channel cannot stop until the foot, at least, of this piece of river is reached.

Since my report was written last January, I have learned that the city engineer has proposed to the council a change in the wharf-line from a point in the vicinity of Lesperance street to the Des Peres, the southern boundary of Carondelet.

I obtained tracings from the engineer showing the location of the proposed line, and had it transferred to our maps in this office. It is shown, on the accompanying outline sketch, in full red lines; the inshore being the building line, the other the low-water line.

Some slight disagreement between the city maps and ours renders the location of this line on our map only approximate where it approaches nearest to Arsenal Island, but the degree of approximation is near enough for the present purpose of discussion.

This line, if approved by the city and constructed as laid down, will so contract the channel to the west of the island as to wash away the greater portion of its western bank, or, failing to do this, the channel will be diverted to the east of the island, rendering it necessary to bring the wharf-line out to its eastern edge. The former can be effected by closing the eastern channel; the latter, obviously, by entirely closing that to the west of the island. This matter, properly speaking, pertains to the city, but as the shape of the wharf from the island down to the Des Peres River bears upon the improvement of Horse-tail Bar, it is necessary to give it more than a passing notice.

It is apparent that the proposed wharf-line will somewhat shorten the low-water

channel, although the degree of shortening will be small, yet a much better line could, it seems to me, be obtained by following more closely the contour of the shore, and yet encroaching enough upon the river to enable the city to gain the wharf-room it seems to need at the foot of the bluffs, along which runs the Iron Mountain Railroad.

The filling up the abrupt concavity in the Carondelet wharf-line and straightening it at that point will be evidently locally beneficial, but in order to follow out that line, or to make a shore-line below the Des Peres conform to it, it will be necessary to straighten and shorten the course of the low-water channel over the bar, which is objectionable if it can be avoided.

Should the channel, however, be thrown by the city to the east of Arsenal Island, its course will bear directly upon the middle point of the concavity above spoken of, which should be then brought to a regular and easy curve, allowing the water to flow off somewhat in the manner indicated by the arrow-line in the sketch; the shore-line below the Des Peres should then be convex toward the river, projecting as far into the river as possible without cutting off the landing at Jefferson Barracks, which is a limit in one direction of any proposed line of improvement. The dotted indigo line on the sketch is as sharp a curve as can well be laid down without cutting off the barracks landing; the tangent-line C E as it approaches the shore above Jefferson Barracks will conform to it as shown by the dotted free-hand curve. This arrangement of the shore-line is not, it must be confessed, pleasing to the eye when taken in connection with the proposed city wharf, but it is advantageous, if we regard the improvement of this bar solely as benefiting the navigation of the river. The low-water channel generally trends towards the Illinois shore as it leaves the Vulcan Iron-Works, and, in rectilinear development, is nearly twice as long as the bar itself, striking the right bank again above the barracks. The bar on the Missouri side is of hard compact gravel, with some sand and rock. No borings have been taken to determine the lay of the rock, but in the joint report of Messrs. Homer and Moulton, to the convention of civil engineers held here, in 1867, it is stated that the rock along the line of the Iron Mountain Railroad dips to the northeast about 1 in 100. The presence of this gravel and rock would alone furnish a strong argument against training the low-water channel *close* along the right bank were it not superseded by other engineering facts stronger yet. In my former communication I mentioned the possibility of the channel getting behind Carroll's Island, if it were trained along the right bank. Even if Carroll's Island slough were closed by a dam, the river would undoubtedly erode a corresponding curve out of the Illinois shore somewhere in the vicinity of the upper part of Carroll's Island, and leave in all probability a bad bar in front of Jefferson Barracks landing, and the barracks must of necessity, so long as it is an important Government station, be easy of access from the river.

The object, then, should be to shorten the course of the channel as little as possible although any plan that may be adopted will shorten it more or less above the barracks, and so hold it, by means of jetties and dams, as to necessitate whatever change may be produced in the bed taking place below Jefferson Barracks landing, where it can be met in the interests of general navigation by means of other works.

It seems to me that we are to be limited in the location of our works at Horse-tail Bar either by an approximation to the dotted indigo line, or by the dotted red line WX, which, whilst it presents a more pleasing appearance to the eye, and may be, perhaps, more advantageous as a wharf-line, produces a further shortening of the low-water channel, which, however, as I have already stated, will obtain, at this point, under *any* plan. The United States magazines are, at present, shut out at low water from direct communication with boats, and the proposed plan will not alleviate this matter. Training the channel along the right bank would undoubtedly deepen the water in front of the magazines; but, in view of the contingencies mentioned above, in case this line were chosen, would the benefits derived be sufficient to pay for the risks or increased expense of diking, when ammunition can be easily taken to any point by means of the Iron Mountain Railroad? It is also apparent that a certain amount of land will be made whatever plan may be adopted, which will accrue to the benefit of those proprietors whose lands happen to lie in the immediate vicinity of the works. The accretions on the right bank would result in the formation of considerable wharf-room between the river and the railroad, which, if within limits, would be an advantage. The astonishing development of the industries of south Saint Louis, and the supplies of iron, coal, &c., brought in by the roads from the south, and from other points, make it more than probable that this front will be occupied before many years with extensive works, warehouses, &c., &c., calling for deep water throughout its length. So that, in considering a plan of river improvement in this vicinity, it seems necessary to avoid any plan that may have to undergo, in future, serious modifications.

Having touched upon the general outline of improvement, it is next necessary to inquire into the form and dimensions of high and low water channels.

The highest water on record here was the flood of 1844, which reached a point 7.58 feet above the city directrix. The lowest water was that of 1863, which was 33.81 feet

below the directrix; the oscillation being 41.39 feet. In 1851 another flood occurred, though it was much lower than that of 1844, only rising 2.80 feet above the directrix. In 1858 the river rose 3.28 feet above the directrix, being 4.30 feet below the level of the flood of 1844.

The flood discharge of 1844 was not measured; neither was the low-water discharge of 1863 ascertained, so far as I can learn.

In Colonel Merrill's report upon the harbor of Saint Louis, it is stated that the discharge of water past the city, as measured by City Engineer Homer, was, August 4, 1865, when the river stood 12.70 feet above lowest water, at the directrix, equal to 211,073 cubic feet, and, on the 24th of October following, when the river-surface stood 19.67 feet above low water, at the same point, the discharge was 384,075 cubic feet. I made an approximate gauging of the river, from a point opposite Carondelet, in May, 1872, when the surface of water opposite the directrix was 20.40 feet above low water, and the river falling, and found the discharge to be 314,859 cubic feet, with mean velocity of 4.49 feet and area = 70,124 square feet.

Mr. McKown, in charge of the surveying party this spring, measured the discharge below Jefferson Barracks, on the 16th and 17th of May, when the Saint Louis gauge read 21.80 feet above low water of 1863, the river falling at the time, and obtained discharge = 368,747 cubic feet, for a mean velocity of 5.005 feet, and area of discharge 73,664 square feet.

On page 79 of the Mississippi River report it is stated that the discharge of the Ohio River in June, 1858, could not have been less than 700,000 cubic feet per second. On page 357 the flood discharge same year past Columbus is given as 1,403,000 cubic feet, so that the flood of 1858, which was greater than that of 1851, must have carried past Saint Louis more than 700,000 cubic feet per second.

In the report of the chief engineer of the Quincy bridge, the oscillation of the Mississippi at that point is said to be 20 feet, the flood discharge = 466,740 cubic feet, and the discharge at a stage of 12.40 feet above low water = 201,185 cubic feet, and for a stage 1.08 feet above low water, 46,796 cubic feet.

The low-water discharge of the Upper Mississippi River, at Keokuk, is stated in General Wilson's report of January 1, 1867, to be 24,883 cubic feet per second, though it was afterward placed at 30,000 cubic feet per second.

Between Keokuk and the mouth of the Missouri are several tributaries, the most important of which, and the largest, is the Illinois River, whose low-water discharge is—I am informed by Mr. R. E. McMath, formerly in local charge of its improvement—less than 2,000 cubic feet. The mean discharge of the Upper Mississippi, as given in the Mississippi River report, is 105,000 cubic feet, and that of the Missouri is 120,000 feet; mean discharge past Saint Louis is, therefore, 225,000 cubic feet. In Appendix E, p. 116, same report, the discharge of the Mississippi River at Columbus, Ky., on the 16th of October, is given at 128,670 cubic feet, this being the united flowage of the Mississippi and Ohio Rivers. In same appendix, p. 114, the discharge of the Ohio River, at Cairo, December 3, 1857, was 183,260 cubic feet, the gauge at Cairo reading 36.18 feet below plane of high water of 1858. At Columbus, same date, it was 220,000 cubic feet, making the discharge of the Mississippi River above Cairo 36,740 cubic feet.

I am informed by C. Shaler Smith, president and chief engineer of the Baltimore Bridge Company, that with the lowest water obtained during his stay at Saint Charles, the measured area of cross-section of the Missouri River at that place was 4,705 square feet, with a mean velocity of 4.165 feet per second, from which the discharge is 19,596 cubic feet. My informant states that the surface of the Missouri River has been, since that time, two feet lower, but, as no soundings were taken for this latter stage, it is possible that more water than the above quantity may have been passing Saint Charles for this lower level, on account of the remarkably shifting nature of the bed of the Missouri. Supposing the Upper Mississippi, and the tributaries between the Missouri and the Ohio, to add an equal amount at a stage of the Mississippi corresponding to that of the Missouri for the discharge of 19,596 cubic feet, we should have for this supposition 39,192 cubic feet passing through the river just above the Ohio, and this agrees closely with the figures from the Mississippi River report, and it also agrees fairly with the Quincy measurements.

It is to be regretted that the assistant in charge of the surveys between Saint Louis and Cairo last fall did not gauge the discharge of the river at the low stage that existed during the greater part of his survey.

Taking all the above figures into consideration, I think we may take the following as discharges past Saint Louis to reason upon:

	Cubic feet.
Flood of 1844	1,200,000
Flood of 1858	700,000
21.80 feet above low water, falling river	368,747
20 feet above low water, falling river	315,000
13 feet above low water	215,000
Mean discharge	225,000
Lowest discharge	36,000

The high water of 1844 endured the greater part of June and the early part of July.

Without going into too great detail, a statement of the average stages of water at Saint Louis for the past two years, or so, will be sufficient for our present purposes.

Month.	Above low water of 1863.	
	Highest.	Lowest.
1870.	*Feet.*	*Feet.*
September	11.81	6.17
October	12.46	9.16
November	17.83	8.34
December	8.36	5.26
1871.		
January	10.66	3.41
February	19.14	7.02
March	21.62	15.66
April	17.25	11.49
May	18.11	13.80
June	16.15	12.37
July	14.03	8.32
August	8.83	6.47
September	6.72	3.95
October	3.93	3.33
November	6.69	3.79
December	8.02	2.84

Month.	Above low water of 1863.	
	Highest.	Lowest.
1872.	*Feet.*	*Feet.*
January	7.10	3.40
February	11.30	7.10
March	10.92	6.40
April	17.65	12.75
May	21.80	13.00
June	23.00	18.00
July	21.60	15.50
August	18.00	9.50
September	9.50	6.80
October	6.75	4.85
November	7.15	3.90
December	4.10	2.50
1873.		
January	10.90	6.80
February	15.50	6.00
March	16.11	7.90
April	26.60	12.10
May	24.50	18.20
June	*25.30	†22.90

* Up to June 3, 1873.

† Up to June 13, 1873.

The following average stages of water, at city directrix, above low water of 1863, may also be stated:

	Feet.
1871—April	14.01
May	14.07
June	14.07
July	11.75
August	7.52
September	4.76
October	3.55
November	5.21
December	5.43
1872—January	4.79
February	8.29
March	8.06
April	15.36
May	18.14
June	20.62
July	17.83
August	12.66
September	8.13
October	5.68
November	5.67
December	3.59

Averaged from reports of city engineer and signal officer.

During the progress of the surveys in the spring of 1872, gauges were placed at Carondelet, and at a point below Jefferson Barracks. Their zeros referred to the level of the city directrix, and the gauges read daily and at the same hour by competent observers, thus enabling the slopes of water-surface between the two to be ascertained by mere inspection of the gauge-records.

The distance between the two gauges, measured along the right bank, was 4.489 miles, or so within, probably, 100 feet.

A mean of 134 gauge comparisons, when the surface of water ranged from 18 to 30 feet below the level of the directrix at the lower gauge, gave a slope per mile of 0.517 feet.

A mean of 16 comparisons, when the surface maintained an average of 30 feet below at same place, indicate a slope of 0.700 feet per mile.

A mean of 22 comparisons, for surface from 30 to 32 feet below, indicate a slope of 0.724 feet per mile.

Forty-four comparisons, for an average of 32 to 34 feet below, indicate 0.695 feet per mile.

Ten comparisons, 34 to 36 feet below, at same point give 0.737 feet per mile.

A grand mean of 226 comparisons, for stages between 18 and 36 feet below, gives an average slope of 0.675 feet per mile.

Thirty-six feet below level of directrix at lower gauge corresponds to a stage of about 4 feet above lowest water at city directrix.

From an inspection of the above data, some idea may be obtained of the requisite

dimensions of channel for different stages, although any calculation would be, at best, approximate, from the nature of the river we have to deal with.

In a report made by the committee, to whom was referred the subject of the regimen of the Mississippi River at Saint Louis, by the convention of engineers before alluded to, there are stated, amongst other facts, that the minimum width of the river at Saint Louis at extreme low water is 1,520 feet and at extreme high water about 2,000 feet; that it would be safe to contract the low-water channel to 1,200 feet, and the high-water channel to 1,800 feet; that the period of floods varies from April to July, though the great floods usually occur in the latter part of June, and are caused by the melting of the northern snows meeting the late spring rains on the lower tributaries, and that the coincidence of these conditions caused the great floods, particularly that of 1844; that the maximum velocity of the current in the main channel, at a depth of 3 feet below the surface, varies from 4 feet per second at the lowest stage to 12½ feet per second for the flood of 1844; and that in surveys covering a space of thirty miles, from the mouth of Missouri River to Jefferson Barracks, the width of the river at extreme low water is found to vary from 2,500 to 900 feet, and that where it is more than 1,200 feet wide a bar exists, either in the middle or at one of the sides.

The conclusion drawn by the committee seems to be that a contraction to 1,200 feet at least at low water is necessary, in order to destroy the bar which obstructs either the middle or one side of the channel. Without, at present, discussing this point, I would merely say that contraction, of itself, does not always alleviate the trouble, for there may be deep water all around the bar, though flowing in a narrow channel; for the discharge is dependent upon the two factors, velocity and area, the latter, in turn, being a function of width and depth, so that a mere contraction may be followed by a local deepening and the bar yet remain. Recent experiments by hydraulicians have shown that in a perfectly regular channel, with banks straight and parallel, it is very generally found that the fillet of maximum velocity is much nearer to one side than to the other; and, as the deposit is generally formed where the velocity is least, we may still look for irregularities, even where the greatest pains are taken to make the bed of the river perfectly regular.

A low-water cross-section of the river, taken at the Pittsburgh coal-dike, where the contraction of the harbor is greatest, made from soundings taken at a mean stage of 7 feet above low water and reduced to plane of low water, contains 24,971 square feet.

A section just below the bridge, reduced as above, gives 23,395 square feet. The mean of the two is, say, 24,000. Of course, these figures are little better than surmises, on account of the movable nature of the bottom, and its change from high water to low water, and *vice versa*. If, however, they are anywhere correct, and the low-water discharge can be taken at 36,000 cubic feet, the mean velocity for the section must reduce to 1.5 feet per second—a figure which could only result from the formation of bars somewhere below, or from a very elongated channel.

For a width of 1,200 feet the product of the velocity by the mean depth would be 30, and supposing the mean depth to be 10 feet, the mean velocity would be 3, sufficient to move along very fine sand at the bottom. (This for a discharge of 36,000 cubic feet.)

A mean discharge of 225,000 cubic feet, with a mean velocity of 5, would call for a cross-section of 45,000 square feet, or, supposing a mean depth of 22 feet, a width of 2,045 feet.

The discharge measured by Captain McKown this year, viz, 363,747 cubic feet, was based upon an area of 73,664 square feet; or, say, for convenience of calculation, 74,000 square feet. The width at the point of gauging was 4,100 feet, giving a mean depth of 18 feet. Were the width reduced to 2,000 feet, the mean depth for this discharge, supposing the velocity to remain the same, would be 37 feet.

Taking the discharge of the flood of 1858 at 700,000 cubic feet, and a width of 2,000 feet, the product of mean depth and mean velocity would be 350; and, if the mean velocity were taken at 7 feet, the depth would be 50 feet; and, if the width were reduced to 1,800, as suggested by the committee above mentioned, the depth required would be still greater.

Now, assuming that the flood of 1844 discharged 1,200,000 cubic feet, and the width of river is reduced to 2,000 feet, for this stage, the product of mean depth by mean velocity would be 600; or, supposing a mean velocity of 8 could be obtained, a mean depth of 75 feet would be required; and, if the width were reduced to 1,800 feet, as the committee suggested, the depth required would be still greater. These figures are merely taken for the purposes of discussion.

Now, in addition to the immense volume of water of floods, we have the enormous quantity of matter brought down in suspension in addition to that carried forward upon the bottom, or scoured wherever the channel is unnaturally contracted.

Where the channel is not contracted, however, the general effect of floods is to silt up the bottom to a certain extent, instead of, as is generally supposed, increasing the depth directly in proportion to the elevation of its surface. This deposit begins to cut out, as the river falls, the scour also depending upon other conditions that cannot always be foreseen. It is only too evident, therefore, in looking at the flood-discharge,

that its flow must not be impeded; on the contrary, it should be assisted. It is commonly remarked that the flood of 1844 passed Saint Louis without undue destruction of property. This may be true, but Saint Louis and her neighbors had not then cramped the area of water-way by closing up Bloody Island Slough, by leveeing the opposite bank, by the construction of the Pittsburgh Dike, and by ridging the American Bottom with high-water levees, and railroad-embankments, &c., &c. The flood-waters had free passage over the bottom, although, from the forest vegetation, which could not but check the velocity in some degree, I am inclined to believe that less water flowed over the bottom per second than has been claimed by some.

It then remains to be seen if the floods can pass Saint Louis restricted to the narrow widths sought by many.

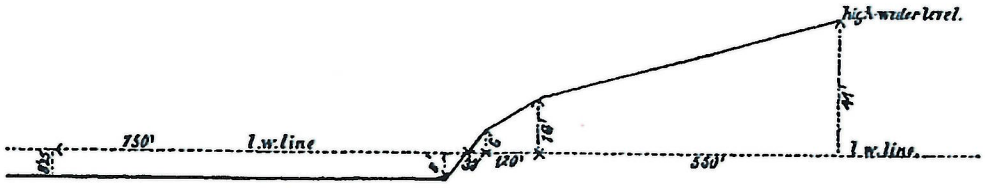
They can only do so in safety to the structures on the banks by scouring out the bottom, which scour depends upon the nature of the bottom. Suppose the flood-scour near the bridge went to the bed-rock. The section, for a width of 2,000 feet at highest water, would be about 180,000 to 200,000 square feet. Assuming the greatest flood-discharge to be 1,200,000 cubic feet, the former figure would require a mean velocity of 6.7 feet, and a mean depth of 90 feet; the latter a mean velocity of 6 feet per second, and a mean depth of 100 feet. Would this velocity keep the bottom clear of material? and where would the material go? To carry the scoured material further down stream would require a uniform section throughout, provided the same velocity were required throughout. It seems hardly necessary to go further, the problem being too uncertain for calculation. Saint Louis may yet find that, in consequence of the contraction of the channel in the immediate vicinity of the coal-dike, and at other points, it will be necessary to provide a flood-weirage behind Bloody Island.

So in the projection of works for the contraction of the channel in the immediate vicinity of Saint Louis, it is better, to my mind, to proceed cautiously, rather under-contracting than over-contracting, and raising the dikes and dams to a moderate height at first.

Where levees are used, as steamboat-landings, &c., the slope has to be taken into consideration for the placing of gang-planks, &c., but, for the upper or higher portion of the levee, where gang-planks would only be thrown during extreme high water, which exists but a short time, it seems to me, that convenience of steamboats can be well sacrificed to the general good, and a much flatter slope put in. In fact, the floating wharves in quite general use at the present, obviate, in great part, the inconveniences arising from too flat levee slopes.

Sketch A shows a semi-cross-section starting from middle of channel, where both banks are to be leveed and brought to within 1,500 feet of each other at low water, which would, it is estimated, pass an 1844 flood with a mean velocity of 11.50 feet per second, supposing that, in addition to the area shown in the sketch, the bottom would still scour out at floods so as to give a further addition to the area of discharge of 12,000 square feet, provided such a velocity could exist for any length of time without tearing up everything in its path, to say nothing of its effects upon floating structures.

"A"



And, if it does not attain sufficient velocity to carry it through this section, will it gain the necessary space by an elevation of its surface, or by scouring and undermining structures?

Such a flood as that of 1844 may never again appear, on account of the progress of agriculture, &c., but it is not within the province of man to predict what may take place as regards floods.

The two plans are indicated on the sketch. For either one, I have approximately located four jetties and one dam, to close up Carroll's Island Slough, numbered, including the dam, from 1 to 5. No. 1 is on the Missouri shore, and is the key of the system; the others are on the Illinois shore.

Possibly a jetty may be required in future below the foot of Carroll's Island, and the position of one is dotted in on the sketch. The low-water way, as defined by the jetties, is about 1,800 feet wide for the present, the structures to be raised to a height of about 6 feet above extreme low water, a necessary height in order that the current may act with sufficient force before the advent of low water, and for sufficient time to prepare the channel for its low-water discharge. It is not presumed that the velocity

for either plan can be excessive, for although the length of the main channel will be curtailed, yet the fall, which at low water has heretofore been measured along a concave bank, will be distributed along a convex one, the two being about of equal length, unless the line W X is adopted, when the channel will be shortened somewhat more; but the channel must be made to regain its length after passing the barracks. For the convex shore-line the jetties are shown in full blue lines. For the line W X the jetties 2 and 3, on the Illinois shore will be lengthened, as shown by the dotted red lines; and jetty No. 1, on the Missouri side, will be shortened by the distance G H.

For the first plan, the length will be—

	Feet.
Jetty No. 1	2,250
Jetty No. 2	900
Jetty No. 3	1,350
Jetty No. 4	2,610
Total	7,110
Add dam (No. 5)	1,950

For the second plan, the length will be—

	Feet.
Jetty No. 1	1,260
Jetty No. 2	1,800
Jetty No. 3	2,100
Jetty No. 4	2,610
Total	7,770
Add dam (No. 5)	1,950

In either case, it would be as well, I think, to limit work at the outset to jetties 1 and 3 and dam 5.

Some revetment at head of Carroll's Island may be needed in future, and I have indicated it in the sketch.

The discharge of the Des Peres and its contributions of material will have to be eventually met also, but this subject is discussed in my report of last January to you.

The sketch accompanying this is a mere outline. More and full information is contained in the complete topographical and hydrographical maps made from the surveys of 1872 and 1873.

I am, Colonel, very respectfully, your obedient servant,

CHAS. J. ALLEN,
Capt. Engineers, and Bvt. Maj., U. S. A.

Col. J. H. SIMPSON,
Corps of Engineers, U. S. A., Saint Louis, Mo.

P. S.—The flat slopes in sketch A are made more to show how flat a levee we can have and then not have enough flood-area, than to indicate exactly what they ought to be at present.

K 9.

EXAMINATION OF THE SAINT FRANCIS RIVER, MISSOURI.

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Louis, Mo., February 11, 1873.

GENERAL: I have the honor to forward herewith report of J. D. McKown, civil engineer, upon an examination of the Saint Francis River.

The law provided for the examination of the "Saint Francis River from Greenville down, Missouri." Mr. McKown carried his examinations considerably below the Missouri State line into Arkansas, connecting with the examinations made upon the Lower Saint Francis by Mr. Koons in 1870. As the party had to pass over this ground below the State line, in order to get out of the river, the additional examination involved no extra cost of any consequence, and had the advantage

1874

Amount appropriated by act approved June 23, 1874	$50,000 00
Amount expended during the fiscal year ending June 30, 1874	51,694 04
Amount available July 1, 1874	52,340 70
Amount required for the fiscal year ending June 30, 1876	80,000 00

(See Appendix I 3.)

4. *Improving Illinois River.*—Owing to the earnest request of the governor of Illinois, and others interested in continuing this improvement in accordance with the approved project of a lock and dam navigation, some four-fifths of the last appropriation were set apart for putting in the lock-bottom for the second lock; this is just below Copperas Creek. The remainder of the appropriation was devoted to dredging at those points most in need of such improvements, in advance of extending the lock and dam system below Copperas Creek.

The amount of $150,000 is asked to be applied to this work in coming fiscal year.

Balance in Treasury of United States July 1, 1873	$95,000 00
Amount in hands of officer and subject to his check	3,719 19
Amount appropriated by act approved June 23, 1874	75,000 00
Amount expended during the fiscal year ending June 30, 1874	52,796 75
Amount available July 1, 1874	118,104 44
Amount required for the fiscal year ending June 30, 1876	150,000 00

(See Appendix I 4.)

IMPROVEMENT OF MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OF THE OHIO, AND IMPROVEMENT OF OSAGE RIVER, MISSOURI.

Officer in charge, Col. J. H. Simpson, Corps of Engineers, having under his immediate orders Capt. Charles J. Allen, Corps of Engineers.

1. *Improvement of Mississippi River between the mouths of the Illinois and Ohio Rivers.*—Work between the Illinois and Missouri Rivers has been limited to the completion of the dam closing the slough behind Ellis Island, opposite Alton, to the height of 8 feet above low water. The materials were purchased in open market and the work done by hired labor.

No specific appropriations are asked for the fiscal year ending June 30, 1876, the amount required being included in general estimate for improvement of Mississippi River between the Illinois and Ohio Rivers.

Amount in hands of officer and subject to his check	$3,021 82
Amount appropriated by act approved June 23, 1874	15,000 00
Amount expended during the fiscal year ending June 30, 1874	3,021 82
Amount available July 1, 1874	15,000 00

Between the Missouri and Ohio Rivers work has been continued at Sawyer's Bend, of which 5,445 lineal feet is now sufficiently protected. The protection will be extended 600 feet the present year, leaving 4,515 feet to be done.

At Venice, what is known as Long Dike has been raised to the height of 14 feet above low water, and the dike extended westwardly 600 feet. Work on the extension was incomplete at the close of the year, but its early completion was assured.

Work was begun at Horsetail Bar, and at the close of the year a decided improvement was obtained, though the incomplete state of the works did not then assure a permanence of decided results. A dike 1,171 feet in length had been completed on the Missouri side, and two dikes on the Illinois side were in an advanced state of progress. The experience gained during the last two years renders the construction of

dikes in the Mississippi a certainty at moderate cost compared with the value of the results attained. The system of construction is no longer experimental, but can be applied generally with assurance of success if skill, care, and forethought be exercised in the location of works and management of construction.

Having passed the experimental stages, the improvement of the Mississippi can hereafter progress as rapidly as the means furnished will permit. The officer in charge estimates that $600,000 will be required for the year ending June 30, 1876, the appropriation of which sum is recommended.

The *triangulation of the river-bed from the Missouri to the Ohio*, which was in progress at the beginning of the year, has been continued, and at the close of the year was nearly completed. In addition to the triangulation special surveys were made at the several points where work is contemplated the present year. The extension of the triangulation to cover the valley proper, mentioned as important last year, is again recommended. The estimated cost is $50,000.

Balance in Treasury of United States July 1, 1873	$239,000 00
Amount in hands of officer and subject to his check, (including $2,712.35 percentage due on contracts not yet completed)	17,531 33
Amount appropriated by act approved June 23, 1874	195,000 00
Amount expended during the fiscal year ending June 30, 1874	215,347 62
Amount available July 1, 1874	236,183 71
Amount required for the fiscal year ending June 30, 1876	600,000 00

(See Appendix K 1.)

2. *Improvement of Osage River, Missouri.*—Operations upon this river were carried on at Dixon's, Round Bottom, Burd's, Lockett's Island, Lockett's, General Bolton's, and Shipley's Shoals, the mode of improvement being the same as that followed during the preceding year, namely, the contraction of the stream by cross-dams, training-dikes, &c., and by excavating the channel. The materials used in the dams and dikes were logs, brush, and stone, and were purchased in open market. The work was performed by hired labor.

Work thus far has resulted in an improvement of the river at the points named, a depth of 2 feet and more at low water having been obtained at most of them.

The further sum of $25,000 was appropriated by the act approved June 23, 1874. It is proposed to expend the greater part of this amount in continuing the work upon the plan now in progress, using the balance, (say, $5,000, or so much of the whole as may be necessary,) for the thorough survey from Tuscumbia—to which point it had been carried and suspended—up the river toward Roscoe, a distance of 173 miles, with a view to the permanent improvement of the river by locks and dams, if such method should be found practicable.

Estimates for the further prosecution of the work are delayed until the completion of the survey referred to for slack-water navigation.

Balance in Treasury of the United States July 1, 1873	$40,000 00
Amount in hands of officer and subject to his check	10,594 74
Amount appropriated by act approved June 23, 1874	25,000 00
Amount expended during the fiscal year ending June 30, 1874	47,332 77
Amount available July 1, 1874	28,261 97

(See Appendixes K 2 and K 3.)

IMPROVEMENT OF THE OUACHITA AND YAZOO RIVERS.

Officer in charge, Capt. W. H. H. Benyaurd, Corps of Engineers.

1. *Improvement Ouachita River in Louisiana and Arkansas.*—Certain amounts of lumber, &c., intended for the foundations of locks at Buffalo

COMMERCIAL STATISTICS.

Statement showing the amount of business done by the St. Louis and Naples Packet Line of steamers on the Illinois River.

	1868.	1869.	1870.	1871.	1872.	1873.
Number of trips made	99	130	105	96	93	101

It may be remarked here that we have kept up this trade constantly and regularly since the year 1849, the number of trips made being governed by the length of the season and stage of water; the greatest number of trips being in 1869, when there was a good stage of water the entire season and no failure to make three trips per week occurred.

Statement of amount of freight carried in 1872 and 1873, and articles transported.

Year.	Grain in bulk.	Grain in sacks.	Flour.	Pork.	Lard.	Apples.	Hides.	Meat in bulk.	Cooperage.	Live stock.	Sundries.
	Bushels.	*Sacks.*	*Barrels.*	*Barrels.*	*Pkgs.*	*Barrels.*	*Pkgs.*	*Pieces.*	*Pieces.*	*Head.*	*Pkgs.*
1872	139,650	175,950	16,400	8,595	3,115	20,000	1,686	66,480	3,377	11,400	8,604
1873	128,330	212,356	15,688	4,846	2,087	12,310	4,254	27,700	4,706	10,545	8,185

In 1872 was about the first of bulk-grain shipments in this trade, and would have been largely increased in 1873 had the stage of water permitted.

C. L. ROGERS,
President Naples Packet Company.

APPENDIX K.

ANNUAL REPORT OF COLONEL J. H. SIMPSON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

UNITED STATES ENGINEER OFFICE,
St. Louis, Mo., August 1, 1874.

GENERAL: I have the honor to submit herewith my annual report of operations for the fiscal year ending June 30, 1874.

In addition to my duties in connection with the works of improvement under my charge, I have been engaged during the year upon miscellaneous work, as follows:

President of board of engineers convened by special orders No. 169, War Department, Adjutant-General's Office, dated August 20, 1873, to examine the construction of the St. Louis and Illinois bridge across the Mississippi River at St. Louis. Original report submitted September 11, 1873, and supplementary report January 31, 1874.

President of the board of engineers constituted by special orders No. 4, paragraph 1, headquarters Corps of Engineers, Washington, D. C., dated January 6, 1872, which assembled in New York City on the 10th of December, 1873, in accordance with Special Orders No. 160, headquarters Corps of Engineers, dated December 3, 1873, to consider and report upon questions relating to the improvement of the harbor of Mobile, Alabama. Report submitted December 12, 1873.

President of the board of engineers constituted by special orders No. 65, headquarters Corps of Engineers, dated June 1, 1874, to consider and report upon the plans submitted by the St. Clair and Caron-

delet Bridge Company for its proposed bridge across the Mississippi River at St. Louis. The meeting of this board, having been deferred, has been fixed for the 3d of August, 1874.

Very respectfully, your obedient servant,

J. H. SIMPSON,
Colonel of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

K 1.

IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS.

ALTON HARBOR.

This improvement consisted in the continuation of the construction of the dam between the head of Ellis Island (opposite Alton) and the Missouri shore; the object being the concentration of the water of the river in the main channel on the east side of the island, and thus the erosion of the shoal in front of the city of Alton at its lower portion.

The work at this locality having been fully described in former reports, it is unnecessary in this report to do more than to report the work done during the fiscal year.

No further appropriation having been made for the year, the operations were confined to the expenditure of the balance of $3,021.82.

The work done was the raising the body of the dam to the height of 8 feet above low water. The work was begun September 20, the materials being purchased in open market, conditional upon delivery in the dam. Favorable progress was made until October 21, when operations were necessarily closed, the means having become exhausted.

The dam was then at the proposed height of 8 feet above low water, except for a distance of about 200 feet, which settled after being brought to height. This settling was local, and must render the body of the dam more compact, if confined to the body of the material; and if due to scour underneath the foundation, the settling can only bring the dam nearer to a condition of stability. As no examination of the work has been made since operations were suspended, no report as to its present condition can be made, except that the break of the water over the dam is continuous, which indicates a good condition. Exact information is not obtainable until the water falls so as to bring the crest of the dam in sight, which will not occur before the latter part of August.

The work done during the fiscal year was the placing—

1,609.04 cubic yards stone, costing	$2,333 11
23 cords brush	56 00
Labor	421 75
Engineering and contingencies	270 96
Total	3,081 82

The original estimate by the board of engineers for the construction of the dam was $40,000. There was appropriated July 10, 1872, $25,000, all of which has been expended.

By the terms of the act approved June 23, 1874, appropriating $200,000 for continuing the improvement of the Mississippi River,

between the mouths of the Ohio and Illinois Rivers, $15,000 of this amount are to be expended between the mouths of the Missouri and Illinois Rivers, which will doubtless prove amply sufficient for the completion of the dam and its protection at the island. This makes up the full amount of the estimate.

Financial statement.

Amount in hands of officer and subject to his check	$3,021 82
Amount appropriated by act approved June 23, 1874, to be expended between the Missouri and Illinois Rivers, from the appropriation of $200,000 for the improvement of the Mississippi River from the Ohio to the Illinois Rivers	15,000 00
Amount expended during the fiscal year ending June 30, 1874	3,021 82
Amount available July 1, 1874	15,000 00

NORTHERN HARBOR OF SAINT LOUIS.

Operations at this locality have been in continuation of the work of the preceding year. The contract awarded to Thomas M. Hackett, for the work at Sawyer Bend, under the appropriation of March 3, 1873, at the opening of bids on the 26th of June, 1873, an abstract of which is contained in the Report of the Chief of Engineers for that fiscal year, page 451, was duly entered into by him on the 16th of July, and closed by payment of retained percentage on January 23, 1874.

Previously-existing contracts under appropriation of June 10, 1872, having expired with the fiscal year, a reletting was authorized May 21, 1873, to cover the unexpended balance of that appropriation, and proposals were opened on the 9th of July, in accordance with an advertisement inviting the same, the contract being awarded to Messrs. Martin Keary & Brothers, the lowest bidders. (See abstract of proposals herewith.) They entered into contract on the 21st of the same month, but after many promises and excuses on their part concerning the commencement of work, I found it necessary, on the 6th of October, to annul their contract in accordance with its terms; and, with the approval of the Chief of Engineers, the work from the 27th of October was carried on under this appropriation, both at Sawyer Bend and Venice dikes, by the purchase of material in open market and the hire of the necessary labor.

Work on Long Dike, at Venice, was delayed so long waiting for the performance of the agreement of Martin Keary & Brothers, that a great part of the working season was lost, whence the work is still incomplete. The results are: the old dike is raised to 14 feet above low water, and of the extension the foundation is all in; the construction of the dike well advanced, and the upper branch of the T built. It is expected that the extension of the dike will be finished by August 1, 1874, leaving a residue of the appropriation unexpended.

The report of the board of engineers, dated April 13, 1872, included the extension of two dikes between Long Dike and Bischoff's Dike, which may ultimately be necessary; but I judge it best to delay the prosecution of additional works at this locality, since, in the interest of economy, it is well to allow the effects of the raising and extension of Long Dike to develop before extending the others, and if any considerable deposit results in the space between Bischoff's and Long dikes, the intermediate dikes will be much less expensive than now. To extend the dikes as proposed, would now cost $100,000.

Mr. Hackett commenced work at Sawyer Bend, under his contract, August 21, or as soon as it was practicable to do so on account of the high stage of water prior to that date. The result of the season's operations under his contract, combined with the work done by purchase of material and hired labor, is 2,520 feet of longitudinal dike, which being added to that previously built by the United States and that undertaken by the board of water commissioners of the city of St. Louis, makes 5,445 feet of the two miles recommended by the board of United States engineers in their report of April 13, 1872.

It is now proposed to devote to the continuation of the work at Sawyer Bend whatever balance of the appropriation of 1872 may remain available after the completion of Long Dike at Venice.

The work at Sawyer Bend during the fiscal year ending June 30, 1875, may with advantage be restricted to the continuation of the protection for a distance of 600 feet. That distance, if the curve be continued, will reach a salient point, which would have to be dredged away this year, but if not touched would be removed by the current by another season. I propose to draw from the appropriation of 1874 sufficient to complete this distance if the balance of the appropriation of 1872 is insufficient.

There will remain, besides this 600 feet, a distance of 4,515 feet to be protected, to carry out the recommendation of the board of engineers, which will require $84,535.52, all of which can be profitably used the coming fiscal year, 1875–1876.

The board of engineers, in their report of April 13, 1872, estimated the cost of protection of Sawyer Bend at...	$142,211 62
And for the extension of the Venice Dikes.....	197,323 90
Making a total for the locality now designated as Northern Harbor of St. Louis	339,535 52
There has been allotted to these works for use up to June 30, 1875	155,000 00
Balance to be appropriated	184,535 52

This sum is judged to be sufficient to complete the works recommended.

For further details of the work in the northern harbor of St. Louis, I refer to the report of Assistant Engineer D. M. Currie, and accompanying tracings herewith.

HORSETAIL BAR.

The work at this locality, being the first undertaken with a view to the improvement of the navigation as a principal object, a detailed description of the plan and the effects designed is given.

Horsetail Bar has always been one of the worst obstructions to navigation at low water below St. Louis. The river then flows over the bar in a broad, shallow sheet, with but little more depth in the channel than elsewhere over the bar. The channel generally trends from the Vulcan Iron-Works landing toward the Illinois shore, thence, returning to the Missouri shore a short distance above Jefferson Barracks, following this shore until the foot of Carroll's Island is reached, when it bears again toward the Illinois shore. The bar is mostly composed of sand and gravel, the latter, with some rock, obtaining on the Missouri side, while the former constitutes the bed of the river on the Illinois side. The formation of the Illinois bank is light alluvion, while the Missouri

side is a rocky bluff from the Des Peres to the Meramec, excepting a comparatively small area of alluvion at the mouth of the Des Peres. This latter area, however, is underlaid by limestone rock, which crops out in one or two places at the low-water line.

The bar is subject to change in size and position, varying with different years, although it is always an obstruction to navigation at low water. In the consideration of a plan for the improvement, the entire stretch of river from the lower portion of Carondelet to the foot of Carroll's Island was included.

Obviously, in order to secure the required depth of channel at low water, a contraction of the width of the stream, by means of jetties, dams, &c., must be resorted to, and the amount of contraction should be sufficient to secure the object in view, and yet not so great as to impede the free discharge of floods. The exact amount of contraction will have to be determined by observation as the work progresses, and on this account it seemed better to limit the lengths of the jetties at first, and push them out from time to time as experience may show to be necessary, rather than to construct them of such lengths at the outset that future necessities may call for their curtailment. The minimum width of the low-water channel between Bloody Island and St. Louis is about 1,500 feet, and it now seems likely that this width will have to be eventually adopted wherever the necessities of navigation and commerce demand deep water all the way across. If, however, *both* banks of the river are to be leveed and brought to this distance from each other, the slopes of the levees will be matters of the first importance, in order that sufficient cross-sectional area may be secured for the flood discharges. The projection of any shore-line on the right bank below the river Des Peres must be governed greatly by the proposed wharf-line of Carondelet, and the necessity of keeping open the landing at Jefferson Barracks. A line meeting the conditions thus imposed was adopted, departing by easy curvature from the proposed wharf-line of the city of St. Louis, where it ends at the river Des Peres, and falling into the natural curvature of the rocky shore about one-half mile above the barracks landing. The river will have to be held to this line by means of jetties on the Illinois side of the river, and further held along the Missouri bluff until the foot of Carroll's Island is passed by closing the slough behind the latter, if a tendency to re-open should be developed. At present it is closed at low stages by a sand-bar. The channel will probably regulate its length by erosion below the island.

The first work will be limited to giving the low-water channel a width of 2,400 feet, and watching the effects, instead of bringing it at the outset to the width stated by the board of engineers of February, 1872, as that which may ultimately be demanded for the harbor of St. Louis when extended over this locality, viz, 1,200 feet to 1,500 feet, and for the reason that no present necessity exists calling for deep water all the way across.

The jetties, as originally proposed, were numbered from 1 to 5, inclusive. No, 1, on the Missouri side, 1,300 feet in length, the outer end of which defines the shore-line on that side. Jetty No. 2, on the Illinois side, may possibly not be needed, but of this more can be told as the work progresses. Jetty No. 3 is to be 1,600 feet in length, and is to serve the double purpose of contraction and shore-defense, and also, in connection with jetty No. 4, which is to be 2,600 feet in length, to force the water against the Jefferson Barracks front. The dam (No. 5) for closing the slough behind Carroll's Island would be 2,000 feet in length, and may be required to secure the maintenance of the low-water

channel to the right of the island; jetties and dam to be raised to a height of about 8 feet above low water, which experience shows to be a favorable height for influencing the low-water channel without interfering with the discharge in times of high water. It is possible that short jetties may be required between jetties 2 and 3 and 4, the approximate lengths of which are respectively 300 feet and 600 feet; but as their necessity would arise solely from the insufficiency of the larger jetties to protect the shore properly, a fact which can only become apparent from the effects of the work, their construction is not now contemplated. The same remark may also be made in regard to revetting the head of Carroll's Island, which may eventually become a necessity.

The estimated cost of the works proposed was:

Jetty No. 1, 1,300 feet, at $18	$23,400
Jetty No. 3, 1,600 feet, at $18	28,800
Jetty No. 4, 2,600 feet, at $18	46,800
Dam No. 5, 2,000 feet, at $18	36,000
	135,000
Contingencies, add 10 per cent	13,500
	148,500

Operations were commenced on the 15th of August, or as soon as the high water would permit, under a contract with the lowest bidder, Mr. Thomas M. Hackett, authorized by your letter of July 3, 1873. (For abstract of bids, see Report of Chief of Engineers, 1873, pages 451, 452.) The work was carried on by the contractor, Mr. Hackett, until the 6th of October, when, he proving incompetent to go on with the work satisfactorily to the Government and agreeably to the terms of his contract, the same was annulled under the authority of the Chief of Engineers, dated September 20 and 29, 1873, and the work prosecuted by the purchase of material in open market and the hire of the necessary labor.

Authority also having been obtained from the War Department, the stone was quarried from the Government tract at Jefferson Barracks.

The plan of the dikes in general is the same as that illustrated in last year's report on the dam or dike for closing Alton Slough, (see Report of Chief of Engineers, 1873, page 442,) and like that for Venice Dike, (see sketches annexed to report of Assistant Civil Engineer D. M. Currie, herewith,) namely, a riprap of stone built 8 feet above low water, and superposed on a foundation or platform of brush from 2 to 5 feet in thickness, and of varying width to suit the height of the dike, held in place by piles until loaded; an apron of brush about 2 feet thick, also held in position by piles and stone, having been previously laid below and alongside the dike, though not connected with it, to prevent the dike from being undermined by the fall of the water over it. The banks at the Illinois shore, which is of an alluvial character, were protected from wash around the ends of the dikes by a small dike 250 feet long built parallel to the shore and at the foot of the bank; and, further, by a spur-dike being built from each end of the dike back and over the bank for a distance of about 100 feet. In addition to this, the main dike itself was carried back over the bank not less than 200 feet.

The main dikes at top have been left 5 feet wide, and the stone, when thrown in, was allowed to take its natural slope.

The work during the year, the details of which will be found in the report of Assistant Engineer Charles S. True, herewith, may be summed up as follows:

Dike No. 1, extending from the Missouri shore 1,171 feet, and 8 feet high above the low water of 1863, completed.

Dike No. 3, extending from the Illinois shore 1,408 feet, and 8 feet high above low water, nearly completed.

Dike No. 4, extending from the Illinois shore 1,126 feet, mainly completed.

The dikes in progress will be completed during the present season, and when their influence is developed at low water, it is probable that another dike will be located and commenced to extend and secure the results obtained.

NEW WORKS PROPOSED.

Improvements at other points are contemplated during the present fiscal year to the extent of the means available, selecting the localities where the obstructions to navigation are most formidable. Following the general principle that the first step in the improvement at any locality is the collection into a single channel of the whole low-water discharge of the river, the work for this season will chiefly be confined at new points to the closing of island chutes. In my report for last year (page 450, Report of Chief of Engineers, 1873) I suggested that it would be advisable, on the score of economy, that the United States should own the principal working appliances which must be used. Experience of the past year has demonstrated this course to be a necessity to the efficient conduct of the work.

Having been compelled to purchase for use on the work a tow-boat, several barges, three pile-drivers, and the tools required in quarrying stone and handling material, it is the intention to use this equipment during the present year, and to make such addition thereto as may be required for the efficient prosecution of the work. The act approved June 23, 1874, providing only $185,000 applicable to the improvement of the river from the Missouri to the Ohio, the number of new points where work can be undertaken this year will be limited to two, namely, Turkey and Devil's Islands. These places are now the worst obstructions between St. Louis and Cairo. The present appropriation, it is hoped, will secure as decided an improvement at these points as has been gained at Horsetail Bar, where, though the works already projected are incomplete and others are yet to be located, the depth of water in the channel is considerably greater than was found at the same stage of water last year.

SURVEYS AND TRIANGULATION.

At the beginning of the fiscal year a party was in the field, in charge of Assistant Engineer I. D. McKown, and had carried the triangulation about thirty miles below St. Louis. The work continued until the latter part of October, when the triangulation was suspended for the season, and the party directed to make special surveys at Devil's, Liberty, and Turkey Islands, Horsetail Bar, and Twin Hollows. These special surveys were completed November 30, 1873, when the party was withdrawn from the field and the survey-boat Arkansas laid up.

The assistants were occupied during the winter in completing and making a projection of the triangulation, giving as the present result a skeleton map filled in with sketched topography, except where the special surveys afforded the detail.

The party was re-organized on the 1st of May, 1874, and at the close of the fiscal year had arrived within seven miles of the mouth of the Ohio.

A special survey was made during May and June, 1874, to determine

the facts, and to correctly connect the present and proposed wharf-line of the city of St. Louis with our surveys. Questions of considerable moment to the general interests of navigation and the exercise of the right of conservancy may be required on the part of the United States. The surveys are complete, and are being plotted in the office. It is deemed advisable to defer the discussion of the subject until the water affords an opportunity to make additional observations.

The surveys ordered during the present season, under the allotment of $10,000 from the appropriation, approved June 23, 1874, for surveys and estimates for the improvements recommended by the Senate Committee on Transportation-Routes to the Seaboard, will be of the character of detailed examination of points where obstructions to navigation are known to exist.

The necessity for a triangulation of the valley proper of the river was shown in the report of 1873. I would respectfully renew the recommendation of the appropriation of $50,000 for this purpose.

Estimates of the cost of completing the improvement of the Mississippi River between the Illinois and Ohio rivers cannot be given. The surveys of the present season will enable me to submit estimates of the cost of removing present obstructions to navigation, but such estimates cannot be expected to cover all that will be required to complete the improvement of a river subject to so many changes as is the Mississippi.

The detailed surveys made during the past season enable me to approximately estimate the cost of works now required at several of the worst places on the river. To improve the navigation at the points where improvement is most urgently demanded, and to carry on the works heretofore undertaken, will require, for the fiscal year 1875 and 1876, the sum of $600,000, the appropriation of which sum is recommended for the improvement of the Mississippi River between the mouths of the Illinois and Ohio Rivers, the distribution of the sum to be at the discretion of the Chief of Engineers.

I am indebted to Hon. John F. Long, surveyor of customs of the port of St. Louis, for certain statistics given in his letter of the 28th of July, 1874, accompanying and forming a part of this report.

Referring to the letter of Mr. Long, I would call attention to the increase of tonnage as conclusive refutation of the oft-repeated assertion that the tonnage on the Mississippi is diminishing, the total increase being 39.7 per cent. of the tonnage of 1870. The steamboat tonnage having increased from 71,489 in 1870 to 76,829 in 1874, or 7.4 per cent., and the barge tonnage during the same period increased from 25,634 to 58,860, or 129.6 per cent., shows that while steamboat tonnage is increasing, the growth of the barge interest is in a much greater ratio. The demand for cheap transportation is doubtless the cause of the ratio being so greatly in favor of barges; but the improvement of the navigation by the removal of dangerous obstructions during the last six years or more, has furnished the opportunity for the change, by rendering barge navigation safe.

The works now in progress and contemplated in the portion of the river under my charge will still further facilitate the cheapened transportation by removing the occasion of delays. Removing the causes of danger and delay, the result will be a safe and expeditious transportation, which is synonymous with cheap transportation.

It is impossible to state in detail what amount of commerce and navigation would be benefited by the completion of the above improvements. Suffice it to say that the whole Mississippi Valley would be greatly benefited thereby.

Financial statement.

Balance in Treasury of United States July 1, 1873:		
On account of appropriation for improvement of Mississippi River from the Missouri to the Meramec, approved June 10, 1872	$42,000 00	
On account of appropriation for improvement of Mississippi River from the Missouri to the Ohio, approved March 3, 1873	197,000 00	
		$239,000 00
On account of appropriation for improvement of Mississippi River from the Missouri to the Meramec, approved June 10, 1872	15,981 33	
On account of appropriation for improvement of Mississippi River from the Missouri to the Ohio, approved March 3, 1873	1,550 00	
		17,531 33
Amount appropriated for improvement of Mississippi River from the Ohio to the Illinois, by the act approved June 23, 1874, $200,000, less $15,000, to be expended between the Missouri and Illinois	185,000 00	
Amount allotted from appropriation, approved June 23, 1874, for surveys and estimates for the improvements recommended by the Senate Committee on Transportation-Routes to the Seaboard, &c., to be expended in the survey of that portion of the Mississippi route lying between the mouth of the Illinois River and the mouth of the Ohio River	10,000 00	
		195,000 00
Amount expended during the fiscal year ending June 30, 1874:		
On account of appropriation for improvement of Mississippi River from the Missouri to the Meramec, approved June 10, 1872	$40,360 09	
On account of appropriation for improvement of Mississippi River from the Missouri to the Ohio, approved March 3, 1873	174,987 53	
		215,347 62
Amount available July 1, 1874:		
On account of appropriation for improvement of Mississippi River from the Missouri to the Meramec, approved June 10, 1872	17,621 24	
On account of appropriation for improvement of Mississippi River from the Missouri to the Ohio, approved March 3, 1873	23,562 47	
On account of appropriation for improvement of Mississippi River from the Ohio to the Illinois, approved June 23, 1874, $200,000, less $15,000, to be expended between the Missouri and Illinois	185,000 00	
On account of allotment from appropriation, approved June 23, 1874, for surveys and estimates for the improvements recommended by the Senate Committee on Transportation-Routes to the Seaboard, &c., to be expended in the survey of that portion of the Mississippi route lying between the mouth of the Illinois River and the mouth of the Ohio River	10,000 00	
		236,183 71
Amount required for the fiscal year ending June 30, 1876, for improvement of the Mississippi River between the mouths of the Illinois and Ohio Rivers		600,000 00
For triangulation of the valley of the Mississippi River between the mouths of the Illinois and Ohio Rivers		50,000 00

Report of Mr. D. M. Currie, Assistant Engineer.

ST. LOUIS, MO., *July* 15, 1874.

SIR: I have the honor respectfully to submit the following report of progress made upon works for the improvement of the Mississippi River at Sawyer and Venice Bends during the fiscal year ending June 30, 1874:

The contract that was awarded to Thomas M. Hackett at the opening of bids in this

office on the 26th day of June, 1873, and of which the abstract was published in the report of the Chief of Engineers for that fiscal year, page 451, for the continuation of the work for improving the Mississippi River at Sawyer Bend under the allotment made for that purpose from the appropriation by act of Congress approved March 3, 1873, was duly entered into by him on the 16th of July following.

Surveys were made of that part of Sawyer Bend lying between the upper end of the works constructed last year and the mouth of the Gingrass Creek in the latter part of July and first part of August, to determine what, if any, changes were necessary to be made in the location of the works or details of the plans. The only change that was made was a slight revision of the location of the longitudinal retaining dike, to make it conform as nearly as possible to the contour of the river-bank, upon which the river had encroached about 30 feet since the surveys were made in August, 1872.

The plan followed in constructing the protecting works was the same as adopted in the construction of similar works at that point during the year ending June 30, 1873, namely, to build a longitudinal retaining dike parallel with the direction that it was intended to give to the bank below mean low-water, and connect this dike with the top of the bank by cross-dikes, built at such intervals as would protect the intervening bank against erosion.

The interval between the dikes that have been built is 120 feet, and, so far as can be seen at this time, they furnish all the protection desired, but if the same system of protection is continued on the remainder of Sawyer Bend, it will become necessary to determine anew the spaces that will be protected by the cross-dikes, because the current impinges against that part of the bank more directly. They vary directly as the product of the length of the dike into the natural cosine of the angle included between the axis of the impinging current and the bank.

To illustrate, let $u =$ the space protected, $x =$ the length of the cross-dike, $y =$ the natural cosine of the angle included between the axis of the impinging current and the bank, and $c =$ a constant whose value is equal to the space protected per unit of dike when the axis of the current is parallel to the bank.

Then $u = c \times y$. If we make $y = 1$, the axis of the current becomes parallel to the bank, and the space protected varies as x. If we make $y = 0$, the expression $c \times y$ reduces to 0, which shows that when the axis of the current is perpendicular to the bank the spaces between the cross-dikes reduces to 0, and that the system of protection becomes a continuous revetment.

The formula $u = c \times y$ furnishes an easy method of determining the space that cross-dikes will protect when the value of c is known.

Mr. Thomas M. Hackett commenced work under his contract on the 21st of August, which was as early as was practicable to do so, on account of the high stage of water that prevailed prior to that date. Even then the water was too high for the dredge to open the trench deep enough for the reception of brush in the foundation of the longitudinal dike, which, according to the plan adopted, was necessary to be done before the construction of the dikes could be commenced; therefore, this operations were necessarily confined to removing a salient point of the bank that projected across the line of the longitudinal dike, near the upper end of the works constructed during the preceding year, while the water remained too high for the dredge to reach the bottom of the trench. It was evident that to enable one dredge to open sufficient length of trench during the season it would have to be pushed to its utmost capacity, and the contractor was permitted to run it night and day. It was unsafe to work all night, however, under a caving bank, and he was able to make only about 16 hours of actual work per day. The dredge with which he commenced work, the Sam Vansant, was hired from H. S. Brown, and completed its term of service on the 6th of September, and from that time to the 16th, when he purchased one, no work was done.

The water reached a stage sufficiently low to render it practicable to commence constructing dikes on the 18th of September, but the contractor was not ready to commence delivering brush and stone in the work until the 3d of October, and then not in such quantities as was desired or that would indicate that he would be able to accomplish any considerable amount of work before the approaching winter would close all our operations on the river for the season.

He was at that time dividing his time and means between this work and that at Horsetail Bar, and was thus trying to carry more work than his means justified. About that time, however, you relieved him from further responsibility of the work at Horsetail Bar, which enabled him to concentrate all of his means and energies here, and told beneficially upon the progress that he made with this work after the 15th of October.

The United States furnished him a pile-driver for the work done during October, one driver being used at both Sawyer and Venice Bends, but after that he was required to furnish one to work under his contract, because one driver could not drive piles fast enough to keep the work moving without interruption at both places.

The progress that was made with the work in the latter part of the season exceeded our most sanguine expectations. This was due more to the unusually fine weather for

working that prevailed in the latter part of November and first of December than to any special effort on the part of the contractor, who, though probably doing the best that he could under the circumstances, was so cramped in his movements for want of means that he could not prosecute the work with any great vigor, and frequently the dredge had to stop working because he was not able to furnish the materials necessary to follow up the opening of the trench with the construction of the longitudinal dike.

The dredge was discharged on the 28th of November, and the last brush of the season placed and sunk on the 1st of December. The contractor continued delivering stone and constructing the longitudinal and cross dikes until the 15th of December, when the river rose to 15.5 feet above low-water and submerged his quarry. Before it fell again sufficiently for him to resume work, the navigation became so hazardous that it was found necessary to suspend for the season. Soon afterward he was paid the retained percentage and other dues on account of his contract, and relieved from its further responsibility. The result of the season's operations is: 2,520 feet of longitudinal dike built, as shown on accompanying map, (A B,) which, being added to that built during the preceding year, and that undertaken by the board of water-commissioners of the city of St. Louis, makes 5,445 feet of the two miles recommended by the board of engineer officers.

The following statement shows the cost of labor and materials used in constructing 2,520 feet of longitudinal dike:

Items and quantities.	Contract price.	Amounts.
1,237¼ hours of actual work of dredge and crew	$9 00	$11,135 25
6,498 linear feet of pile-timber	6	389 88
124 piles driven 6 feet, (driver furnished by United States)	2 00	248 00
185¼ linear feet of piles driven in excess of 6 feet, (driver furnished by United States.)	20	37 10
120 piles driven 6 feet, (driver furnished by contractor)	4 00	480 00
6 linear feet of piles driven in excess of 6 feet, (driver furnished by contractor)	30	1 80
8,510.99 cubic yards of stone as wet riprap	1 40	11,915 39
443.73 cubic yards of stone as dry riprap	1 50	668 59
15.9 cubic yards of earth, (dry excavation)	20	3 18
3,642.36 cords of loose brush, second grade	2 40	8,741 66
86 hours' labor of men trimming bank preparatory to dredging	25	21 50
Total amount	.....	33,642 35

Bids were received and opened in this office on the 9th of July for furnishing and delivering materials, and doing all the work required for the improvement of the Mississippi River at Sawyer and Venice Bends under the unexpended balance of the appropriation for the improvement of the Mississippi River between the Missouri and the Meramec, made by act of Congress approved June 10, 1872, and the contract was awarded to Messrs. Martin Keary & Bros., they being the lowest bidders. They entered into contract on the 21st of the same month. No work was done under that contract, however, although it was in force until the 6th of October, when you found it necessary to annul it for non-fulfillment of its terms on the part of the contractors; after which the work at Sawyer and Venice Bends under that appropriation was carried on by hiring labor and purchasing materials in open market.

SAWYER BEND.

The work was commenced at Sawyer Bend on the 27th of October, and continued, with slight interruptions, until the close of the year, and consisted in completing and repairing the work done during the year ending June 30, 1873, and in building cross-dikes for the protection of the bank, stone for which was obtained from quarries on the river, and transported on barges while navigation remained open, but after its close it was obtained from a quarry on Broadway in this city, and hauled on wagons to the work.

The results of the operations during the year are:

The works left unfinished at the close of the preceding year were completed; those that were damaged by high-water were repaired; and 21 cross-dikes were built for the protection of 2,520 linear feet of bank, shown on the accompanying map between the points marked A and B.

Protection by cross-dikes instead of by continuous revetment, was adopted on account of the satisfactory results obtained when they were tried as a temporary expedient, and has stood the test of two high-water seasons, proving itself a sufficient protection at a less cost.

The amount of money expended for labor and materials used in the construction of

21 cross-dikes, and the repairs and the completion of works, is shown in the following statement:

Items and quantities.	Price.	Amount.
3,581.17 cubic yards of stone as dry riprap	$1 39	$4,977 82
3,875.22 cubic yards of stone as wet riprap	1 27	4,921 52
203.37 cubic yards of spalls	1 33½	271 16
2,124½ hours' labor of men	22½	478 01
Total		10,648 51

VENICE BEND.

The work at Venice Bend was raising and extending Long Dike, and was in continuation of that commenced there during the fiscal year ending June 30, 1873.

Peculiar interest attaches to the extension of that dike, on account of the difficulties which had to be overcome in its construction. I therefore submit with this report diagrams showing the plan of its construction in detail. This plan is slightly modified from that originally intended, in this, that whereas the original contemplated having the cross-dike or T extended below as well as above the main dike, the upper branch only has been built; and as there is no scour below now, it is hoped that it will not be necessary to build that branch. Of this, however, nothing very definite can be said until after a low-water season shall have passed. If no scour exists, then a great saving will have been made in the cost of the dike by leaving off the lower branch of the T, and if scour sets in we will have only to build it as originally contemplated, and with no more difficulties or expense than would attend its construction now.

The work was commenced on the 14th of October and pushed as rapidly as materials could be procured, and the necessary labor performed with the means at hand, until the 15th of December, when the high water rendered it impracticable to work; and before the flood passed the navigation became so hazardous that we had to suspend operations, not, however, until we had completed the foundation of the extension, including the upper branch of the T.

The work was resumed on the 10th of April, but, on account of the tempestuous weather and high water, very little progress was made until after the 1st of May, when, the weather and stage of water being favorable, the work wa spushed and good progress made until the 10th of June, when the high-water and consequent strong current caused a suspension until the 26th, when it was resumed.

The results are: The old dike is raised to 14 feet above low-water, and of the extension the foundation is all in, the construction of the dike well advanced, and the upper branch of the T built.

The following statement shows the expenditures made for labor and materials used in raising and extending Long Dike during the year:

Items and quantities.	Price.	Amount.
12,557 linear feet of pile-timber	$0 06	$753 42
1,660.65 cords of loose brush, second grade	2 10	3,487 36
3,155 cubic yards of stone as wet riprap	1 27	4,006 85
6,112.39 cubic yards of stone as dry riprap	1 39	8,496 22
4,202 5 linear feet of piles driven	25	1,050 63
15.5 hours' labor of men	22	3 41
164.5 hours' labor of men	22½	37 01
Total		17,834 90

Accompanying this report are two tracings, one a map of part of St. Louis Harbor, showing location of the works referred to at Sawyer and Venice Bends, scale $\frac{1}{30000}$; the other, plan and sections of the extension of Long Dike, Venice Bend showing details of construction; scale of plan showing entire dike, $\frac{1}{1320}$; scale of detail plan and sections, $\frac{1}{120}$.

Very respectfully, your obedient servant,

D. M. CURRIE,
Assistant Engineer.

Col. J. H. SIMPSON,
Corps of Engineers, U. S. A.

Abstract of proposals for the improvement of the Mississippi River at the northern harbor of St. Louis, opened at engineer office, United States Army, St. Louis, Mo., July 9, 1873.

Bidders' names and residences.	Guaranteed.	Certified.	Loose brush, 1st grade, 1,000 cords.		Loose brush, 2d grade, 2,000 cords.		Rafted brush, 1,000 squares.		Pile-timber, 15,000 feet.		Stone for dry riprap, 8,000 cubic yards.		Stone for wet riprap, 12,000 cubic yards.		Spalls, 3,000 cubic yards.	
			Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.
Thomas M. Hackett, St. Louis, Mo	Yes.	Yes.	$3 00	$3,000 00	$2 75	$5,500 00	$6 00	$6,000 00	$0 06	$900 00	$1 50	$12,000 00	$1 50	$18,000 00	$1 50	$4,500 00
Barker, Whittlesey & Co., Fayetteville, N.Y	Yes.	Yes.	4 00	4,000 00	3 00	6,000 00	6 00	6,000 00	04	600 00	2 00	16,000 00	2 00	24,000 00	1 00	3,000 00
Richard J. Tunstall, St. Louis, Mo	Yes.	Yes.	3 50	3,500 00	3 00	6,000 00	5 50	5,500 00	06	900 00	1 75	14,000 00	1 60	19,200 00	1 00	3,000 00
Willard Johnson, Fulton, N. Y	Yes.	Yes.	3 50	3,500 00	3 50	7,000 00	6 00	6,000 00	06	900 00	2 00	16,000 00	2 00	24,000 00	1 50	4,500 00
Martin Keary & Bros., St. Louis, Mo	Yes.	Yes.	2 89½	2,895 00	2 09	4,180 00	2 47½	2,475 00	05½	825 00	1 39	11,120 00	1 27½	15,300 00	1 32½	3,975 00

Bidders' names and residences.	Gravel, 3,000 cubic yards.		Excavation, dry, 20,000 cubic yards.		Transportation of stone, 2,000 cubic yards, 100 feet.		Piles driven 6 feet, 600 piles.		Piles driven in excess of 6 feet, 1,200 feet.		Labor of men, 1,000 hours.		Labor of teams, 800 hours.		Total.
	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	
Thomas M. Hackett, St. Louis, Mo	$2 00	$6,000 00	$0 20	$4,000 00	$0 09	$180 00	$2 00 4 00	$1,200 00 2,400 00	$0 25 40	$300 00 480 00	$0 25	$250 00	$0 50	$400 00	$62,230 00
Barker, Whittlesey & Co., Fayetteville, N.Y	1 00	3,000 00	40	8,000 00	10	200 00	60 80	360 00 480 00	15 20	180 00 240 00	25	250 00	40	320 00	71,910 00
Richard J. Tunstall, St. Louis, Mo	1 05	3,150 00	20	4,000 00	10	200 00	2 00 4 00	1,200 00 2,400 00	20 40	240 00 480 00	35	350 00	70	560 00	61,800 00
Willard Johnson, Fulton, N. Y	1 00	3,000 00	30	6,000 00	10	200 00	36 72	216 00 432 00	15 30	180 00 360 00	25	250 00	50	400 00	72,146 00
Martin Keary & Bros., St. Louis, Mo	2 19	6,570 00	19	3,800 00	02	40 00	2 07½ 4 10	1,245 00 2,460 00	17½ 35	210 00 420 00	22½	225 00	42½	340 00	53,200 00

Report of Mr. Charles S. True, Assistant Engineer.

ST. LOUIS, MO., *July* 14, 1874.

SIR: I submit to you the following report of work done under my supervision during the fiscal year ending June 30, 1874, for the improvement of the steamboat channel of the Mississippi River, at Horsetail Bar, which work was placed in my charge July 18, 1873.

On the 22d of July, 1873, the day your plan for the year's work was approved, the river was too high for work to be done advantageously, but about that time the water commenced falling rapidly.

A reconnaissance of that part of the river, including Horsetail Bar, made on the 11th and 12th of August, by Maj. C. J. Allen, Mr. R. E. McMath, and myself, showed that the water of the river at that time was too much diffused over the broad sandy bottom to mark out for itself any well-defined low-water channel. The water divided into three principal parts just below the southern limit of St. Louis, one portion following the Missouri shore into the bend below the mouth of the river Des Peres, a larger part crossing the gravel head of Horsetail Bar in a broad sheet too shallow for steamboat navigation, then flowing in a deep channel near the Illinois shore to the head of Carroll's Island, where it divided into two parts, one to go down the chute to the east of the island, and the other to again join the main river below Jefferson Barracks, while the main and only navigable part of the river passed between the high sand of Horsetail Bar and the rocky Missouri shore on which Jefferson Barracks stands.

The river had fallen to 12 feet above the low-water of 1863 on the 12th of August, and material could be profitably used in the construction of the proposed dikes. The contractor, Mr. Hackett, was therefore ordered to begin work immediately, and on the 15th of August he commenced operations. The first rock was put into dike No. 1 on the 19th of August, and dike No. 4 was begun September 5.

Three pile-drivers, built for work on the improvement of the Mississippi River, were turned over to the contractor at Horsetail Bar August 22, and on the 8th of September pile-driving at dike No. 1 was commenced. Three hundred feet of the western or Missouri end of this dike is founded on solid rock, while all the outer portion rests on sand. The part founded on rock was built in a narrow ridge raised 8 feet above low-water, the top finished 5 feet wide, and the sides sloped at an angle of about 45°. On the sand foundation, where piles could be driven, an apron of green brush, 2 feet thick and 25 to 30 feet wide, was laid just below the dike, to prevent the overflow of water from undermining it. To hold this brush in the current and admit of its being sunk in its proper place two rows of piles were driven, 10 feet apart, and with the piles 7 feet apart in the rows; the brush was then placed on top of the water, interlaced among the piles, and loaded with rock till it sunk to the bottom, and enough additional rock was put on to hold it in place. A heavier mat of brush was put in as a foundation for the main part of the dike, and held in place by one row of piles. Rock was put on this foundation till the dike was raised 8 feet above the low-water line of 1863, and finished 5 feet wide on top.

At the outer or channel end of dike No. 1 a cross-dike or T-head, 75 feet wide and 210 feet long, was built on a foundation of brush. To lay this foundation, piling was driven in rows across the T-head, beginning at the down-stream end, and the brush was put in in sections. This part of the work was done in a strong current of water from 12 to 20 feet deep, and the brush was put in and sunk in thin layers, as the piling would not stand against the pressure of a large body of brush.

During the month of September the weather was fine and the stage of water the best that could be had for successful work on the dikes. Everything that could be done by the officers of the Government in charge to hasten the work was done, yet the progress made was not as great as was desirable. Before the foundation of the T-head was in, or that of the main stem of dike No. 1 finished, it became evident that the contractor could not carry out his contract, and that sooner or later he must suspend work entirely. Foreseeing this, you had asked for authority to annul the contract and to continue the work by purchasing material and labor in open market, if it should become necessary to do so. At the close of September it was decided to annul the contract, but Mr. Hackett was allowed to continue work till the 6th of October and until arrangements could be perfected for continuing the work by the hire of labor and purchase of material in open market.

By application through the Chief of Engineers authority of the Secretary of War to quarry rock for the work on the Government reservation at Jefferson Barracks was granted October 2, 1873. On the 7th of October a steam tow-boat was chartered, with the privilege of purchasing her, and two barges were bought and six hired, to transport brush and stone; and on the 8th work was resumed by the United States on the main stem and T-head of dike No. 1 and on the shore ends of dikes No. 3 and No. 4.

The eastern ends of dikes No. 3 and No. 4 were built on a steep bank of alluvion, and the bodies of the dikes were founded on sand. To prevent the water washing around the shore ends, a small dike 250 feet long was built parallel to the shore at the foot of the bank, and three spur-dikes were built from this over the top of the bank.

The main parts of dikes No. 3 and No. 4 were carried out in line with the central spur-dikes, and were built with aprons and foundations of brush similar to dike No. 1.

As necessity for more barges arose, two were hired and four bought for the work, and on the 1st of December the steamer Anita, which had been chartered for a tow-boat, was bought by the Government.

In the latter part of November the outer end of dike No. 3 reached the deepest part of the eastern channel, where the water was 25 feet deep and the current quite strong. The work of putting in piling and brush there was slow, and it was decided to continue the dike of rock only. An apron of small stone, some two feet thick and extending 70 feet below the line, was first laid, and the dike raised by putting in rock on line and letting it find its own slope.

A rapid rise in the river began December 10, and on the 13th the water was so high as to stop all work. The chartered barges were returned to their owners and the Government boats and barges all laid up in a safe winter-harbor.

The work done during the season of 1873 was: Dike No. 1, completed. Of this dike 416 feet was built wholly of rock and 755 feet was built with a brush foundation. Dike No. 3 had its shore end built of rock, 400 feet of the main dike finished on a brush foundation, and a foundation of small rock carried out 250 feet further. Dike No. 4 had shore end built of rock, 525 feet of brush apron, and foundation put in, and the dike on it nearly completed.

During the winter some work was done on the steamer Anita, and barges No. 1, No. 3, No. 4, and No. 5 were docked and recaulked. The river remained open all winter.

Work at the quarry was commenced again the 7th of April. The foundation of dike No. 3 was extended to the sand-bar, of rock only, and the dike has since been raised to nearly its full height. Work on dike No. 4 was begun May 20, and a rock apron was built out 400 feet. The stage of water during the spring and thus far during the summer has been uncommonly low for the time of year, and favorable for work in the river.

The condition of the dikes June 30, 1874, was: No. 1, completed; and it stopped the lower currents from following the Missouri shore, and thus concentrated the water in the main channel. Dike No. 3 joined the main Illinois shore and the sand-bar, and had assumed the nature of a dam. It was not raised to its full height, but it had the effect of stopping a large part of the water that otherwise would have gone down the chute and forcing it back into the main channel. Dike No. 4 had not been extended far enough to have any action on the main channel, and acted only as an auxiliary to No. 3 in stopping the channel next the Illinois shore.

The lengths of dikes built and the total amount of material put into them during the year are:

Dike No. 1, 416 feet, of rock only, and 755 feet of rock on brush foundation, using 1,755.25 cords brush, 11,149 linear feet of pile-timber, 12,323.78 cubic yards rock for riprap.

Dike No. 3, shore-end 208 feet, built of rock, 400 feet of main dike of rock on brush foundation, and 800 feet partly built of rock only, using on the dike 371.80 cords brush, 7,053 linear feet pile-timber, 16,983.35 cubic yards rock for riprap.

Dike No. 4, shore-end 201 feet long, of rock, 525 feet of main dike nearly completed, of rock on a foundation of brush, and 400 feet of rock foundation put in for extension of dike, using 792.26 cords brush, 8,064 linear feet pile-timber, 10,278.68 cubic yards rock for rip-rap.

I have the honor to be, most respectfully, your obedient servant,

CHARLES S. TRUE,
Assistant Engineer.

Col. J. H. SIMPSON,
Corps of Engineers, U. S. A.

Commercial statistics.

CUSTOM-HOUSE, ST. LOUIS, MO.,
Surveyor's Office, July 28, 1874.

SIR: Respectfully acknowledging receipt of your communication of 24th instant, I would reply to its inquiries as follows:

1. St. Louis is a port in the collection-district of New Orleans, though entirely independent of that port.

2. The revenue collected through this office for the year ending June 30, 1874, was $1,434,224.75, from the following sources:

Import duties	$1,407,910 33
Steam-vessel inspections	15,471 62
Hospital fees from seamen	10,842 80

The tonnage of this port at this time is as follows:

	No.	Tons.
Steam-vessels	170	76,829
Barges	161	58,860
Total	331	135,689

Which compares with the tonnage in the year 1870 as follows:

	No.	Tons.
Steam-vessels	166	71,489
Barges	70	25,634
Total	236	97,123

This comparison is interesting, too, as showing the growth of barge-transportation; a growth which will, in my opinion, be more rapid still from this time forward.

Trusting the foregoing may be of some slight service,

I am, very respectfully,

JOHN F. LONG,
Surveyor of Customs.

Col. J. H. SIMPSON, *U. S. A.*

K 2.

IMPROVEMENT OF OSAGE RIVER, MISSOURI.

The plan of operations for improving the Osage River during the fiscal year ending June 30, 1874, was the same as that followed during the preceding year, viz; the construction of cross-dams and training-dikes, together with the excavation of the channel, with a view to obtain at all times, if possible, a depth of water at the shoalest parts of at least 2 feet at the lowest stage of the river.

As stated in my report for last year Mr. Howard Cook, the contractor for dredging, having procured a dredge which he felt confident would perform the work under his contract, asked for an extension of time in which to execute the work. This was granted under the authority of the Chief of Engineers, to include the 31st of December, 1873; but after diligent efforts upon his part to carry on the work, he found that he was unable to do so, and asked to be relieved from his contract. Being assured that the retirement of Mr. Cook would not be detrimental to the interests of the Government, as hired labor could do the work more suitably, and, as I believed, at a cheaper rate and with more economy, and as the current caused in the channel by the erection of dams was expected to erode the bottom, and thus diminish the amount of dredging, I recommended that he be relieved from the obligations of his contract. This was granted under date of September 2, 1873, by the Chief of Engineers, and payment made of the amount due thereon.

The entire work then was prosecuted by the hire of labor and purchase of material in open market.

Operations were carried on under a balance of $50,594.74 of the three appropriations of $25,000 each, approved respectively March 3, 1871, June 10, 1872, and March 3, 1873, and the work confined to the improvement of Dixon's Round Bottom, Burd's, Lockett's Island, Lockett's, General Bolton's, and Shipley's Shoals.

At Dixon's Shoal the work previously commenced was continued, and resulted in the completion of a training-dike 2,003 feet in length, 3½ feet above low-water, and with a slope of 1 to 1, on the channel-side, and on the opposite side a slope of 2 to 1, and a flat surface on top of

1875

The canal commissioners speak in most favorable terms of the work which was done for them by the United States Government.

The project for continuing the work of improving the river, by dredging and building dams for contracting the low water width, was satisfactorily carried out during the last fiscal year, and has already afforded greatly-increased facilities to the navigation.

The sum of $122,000 is asked for completing this improvement, with the recommendation that $20,000 thereof be applied to the purchase of a dredge and equipment, for the purpose of affording immediate relief at points liable to sudden obstruction, and also to be used in widening channels heretofore opened of merely practicable width.

Balance in Treasury of United States July 1, 1874	$75,000 00
Amount in hands of officer and subject to his check (including $2,818 percentage due on contracts not yet completed) July 1, 1874	45,922 44
Amount appropriated by act approved March 3, 1875	75,000 00
Amount expended during the fiscal year ending June 30, 1875	82,796 02
Amount available July 1, 1875, including $11,557.43 due on contracts	113,126 42
Amount required for the fiscal year ending June 30, 1877	122,000 00

(See Appendix K 4.)

IMPROVEMENT OF MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS, AND IMPROVEMENT OF OSAGE RIVER.

Officer in charge, Col. J. H. Simpson, Corps of Engineers, having under his immediate orders Capt. C. J. Allen, Corps of Engineers.

1. *Improvement of the Mississippi River between the mouths of the Illinois and Ohio Rivers.*—The dam opposite Alton has been repaired and raised to the height of 10 feet above low water, and is now considered complete, but will require repairs from time to time.

The unexpended balance of the $15,000 required by act approved June 23, 1874, to be spent between the Illinois and Missouri, shown in the accompanying financial statement, together with $15,000 similarly appropriated by act approved March 3, 1875, will be expended in a dam at Piasa Island.

Below the Missouri the protection of Sawyer Bend has been extended 750 feet. No work is contemplated here the present year except repairs.

Long Dike, near Venice, has been completed, but, having been injured by the heavy ice of the past winter, will require repairs.

Work has been continued on the dikes on the Illinois side at Horsetail Bar with favorable results. The channel during the last low-water season was materially deepened over the crossings, from 5 to 7 feet; but as the channel had not at that time reached its permanent shape and position, the improvement is reported incomplete, though progressing satisfactorily. Work will be continued the present season.

Dams at Fort Chartres, Towhead and Turkey Island, were commenced during the year; a good depth of water, 8 feet, was maintained during low water on the bar at Turkey Island. These dams will probably be finished the present season.

A dam at Liberty Island will be commenced this year, which the means available will not complete.

At Devil's Island, a dike in the Missouri Chute was constructed, with the view of re-opening it for navigation, by deepening the water on the obstructed crossing to 9 feet, which was accomplished in October, 1874, when, the dams closing, the Illinois chutes were commenced.

Satisfactory progress was made on these dams, which will be continued the present year.

Surveys and estimates for the continuation of these improvements were made, and the results reported as part of the *third subdivision of Mississippi transportation route to the seaboard.* The improvement already accomplished under the comparatively limited appropriations heretofore made for this important work induce the recommendation for the grant of means adequate to a vigorous prosecution of it throughout its whole length.

The officer in charge estimates that $1,000,000 could be profitably expended during the year ending June 30, 1877, the appropriation of which sum is recommended.

The triangulation of the river from the Missouri to the Ohio has been completed. A similar triangulation from the Illinois to the Missouri is much needed, as also the triangulation of the valley proper, recommended in previous reports. The estimated cost of this survey is $50,000, the appropriation of which sum is recommended.

Balance in Treasury of United States July 1, 1874	$210,000 00
Amount in hands of officer and subject to his check July 1, 1874	41,183 71
Amount appropriated by act approved March 3, 1875	200,000 00
Amount expended during the fiscal year ending June 30, 1875	242,846 29
Amount available July 1, 1875	208,337 42
Amount required for the fiscal year ending June 30, 1877	1,050,000 00

(See Appendix L 1.)

2. *Improvement of the channel of the Mississippi River opposite Saint Louis by closing Cahokia Chute.*—In consequence of a resolution of the Committee on Commerce of the House of Representatives, communicated to the Secretary of War January 12, 1875, Colonel Simpson, as the officer in charge of the river improvements in that locality, was directed to communicate any information in his possession upon the question of closing the channel east of Arsenal Island, known as Cahokia Chute, in consequence of the probable effect of the construction by the city of Saint Louis of a dike projecting into the river. The desired information was accordingly transmitted, and printed in H. R. Ex. Doc. No. 165 of the last session of Congress.

Colonel Simpson makes no recommendation, but reports the subject as deserving the attention of Congress and of such legislation as will define the rights of the several parties interested.

The harbor lines of the city of Saint Louis should conform to the requirements of the improvements in that harbor and the channels leading to it, now being made under appropriations of Congress for that object; and I would recommend that Congress authorize the Secretary of War to establish the harbor and channel lines of the Mississippi at and near the city of Saint Louis.

(See Appendix L 3.)

3. *Improvement of Osage River, Missouri.*—Work was carried on under an unexpended balance of the appropriation of March 3, 1873, amounting to $3,261.97, and the appropriation of $25,000 made by the act of June 23, 1874, and confined to the improvement of Sugar Creek, Schiefer's, White Oak, Bois Brulé, Bolton's, Rice's, Prince's and Shipley's Shoals. The work at Sugar Creek and Bois Brulé Shoals consisted in removing the snags from the channel and cutting the leaning timber from the banks, and that at Schieller's, White Oak, Rice's, and Prince's in the excavation of the channel to secure a depth of 2 feet. At Burd's Shoal the dam was repaired and the channel excavated. A training wall 1,050 feet, and a cross dam 775 feet in length, were built at Bolton's Shoal, and at Shipley's Shoal the cross-dam was repaired and a bar removed by excavation at the foot of the shoal.

Prism of canal from guard to middle lock.

150,000 cubic yards rock-excavation, at $2.50	$375,000 00
10,000 cubic yards earth-excavation, at 50 cents	5,000 00
Channels at entrance to canal.	
22,700 cubic yards rock-excavation, at $1	90,800 00
Channel at Montrose chain.	
42,000 cubic yards rock-excavation, at $8	336,000 00
	866,485 00
Add 10 per cent. for contingencies	86,648 50
Total cost of increase of 1 foot in depth	953,133 50
The work has already cost, up to the present time, and including the appropriation of June 23, 1874	$3,571,000 00
Amount estimated to complete it	480,000 00
Total cost, according to present plans	4,051,000 00
Increased cost for 1 foot additional depth	953,133 50

I confidently expect to bring this work to such a state of completion by the fall of 1875 as to allow of the passage of steamboats; if, however, the plan is so changed as to require the additional foot in depth, the completion of the work will be delayed at least two years.

Very respectfully, your obedient servant,

AMOS STICKNEY,
Captain of Engineers, Brt. Major.

Col. J. N. MACOMB,
Corps of Engineers, U. S. A.

CC 4.

PART OF THIRD SUBDIVISION OF MISSISSIPPI TRANSPORTATION-ROUTE.

REPORT OF COL. JAMES H. SIMPSON, CORPS OF ENGINEERS.

ENGINEER OFFICE, UNITED STATES ARMY,
Saint Louis, Mo., January 20, 1875.

GENERAL: In accordance with your letters of June 29 and July 22, 1874, requiring me to survey that portion of the Mississippi River lying between the mouth of the Illinois River and the mouth of the Ohio River, under the act of Congress approved June 23, 1874, containing an appropriation for surveys and estimates for the improvements recommended by the Senate Committee on Transportation-Routes to the Seaboard, &c., and to submit for approval a project for the improvement of the river between the points mentioned, I have the honor to present the maps herewith and the following

REPORT.

The Mississippi River, between the Illinois and Ohio, is divided by natural characteristics into three sections.

The first, extending from the Illinois to the Missouri, a distance of twenty-four and a half miles, is distinguished from the other sections by comparatively clear water, discolored by earthy and vegetable matter, but not sufficiently charged to afford a sediment when the river is below

the mean stage, so long as the water is in motion; becoming turbid as the river rises, sand, clays, and fine gravel are borne along in considerable quantities; the alluvial banks are eroded, and this portion of the river becomes assimilated to the section below the Missouri when that section is below the mean and approaching the low stage.

The average slope of this section at low water is 0.440 foot per mile, and the current strong. The slope and current depend very much on the relative stages of the Upper Mississippi and the Missouri Rivers, increasing or diminishing as the relative volume of the Mississippi increases or diminishes.

From the mouth of the Illinois to Alton, a distance of sixteen and a half miles, the eastern shore of the river is a rock bluff rising to a height of from 75 to 150 feet, except where broken by ravines and the narrow valleys of unimportant creeks. On the west the bank is continuously alluvial, and the bottom-lands are common to the Mississippi and Missouri Rivers, here separated by a neck of land from two to four miles in width.

The second section extends from the mouth of the Missouri to Commerce, a distance of one hundred and sixty-two miles. This section derives its distinguishing features from the Missouri; turbid waters, shifting bars and channels, rapid erosions of alluvial banks, and extensive accretions, building up and removing islands, tow-heads, and battures, with great rapidity.

Seen at the higher stages, the crumbling banks falling in masses, the spoil of the forests covering the surface, and the boiling, swirling current show the power to be encountered; and seen at low water, the wide wastes of sand-bars, bristling with snags, and drifts of every size and shape, with here and there the dismembered skeletons of man's work, memorials of disaster, as forcibly suggest that to undertake the control of the forces here developed is no light task.

From the mouth of the Missouri to Saint Louis, a distance of fifteen miles, the river does not touch the bluff on either side. A prolongation of the rock-formation of the west side is exposed at the chain of rocks, where a ledge extends about one-third of the distance across the river-bed. The rock probably underlies the alluvium on the Missouri side, at no great depth, for a considerable distance below the chain. With these exceptions—and the latter is not positively proven—there is nothing to check erosion on either side of the river from the mouth of the Missouri to Saint Louis.

Below Saint Louis the river follows the Missouri bluff closely for fifty-five miles, the only exception being at Rush Tower Bend, where a former island has become connected with the Missouri shore. Above Saint Genevieve the river leaves the bluff, returning to it near Saint Mary's. Below Saint Mary's it trends to the eastward, meeting the Illinois bluff at the mouth of the Kaskaskia, and follows this bluff to Liberty, whence it again is turned toward Missouri, reaching the bluffs at Big Eddy, and follows close at their foot to Cape Cinq' Homme.

Here the valley is at its narrowest, and rock appears on both sides. The main Illinois bluff recedes from the river near Liverpool, and the river continues along the Missouri bluff. A few miles below, the isolated bluffs near Grand Tower are found, on the Illinois side. Low grounds to the eastward of these isolated islands of rock indicate that the river once flowed to the eastward of them, and that the opening through which the river now flows is the result of some unknown operation of nature.

Below Grand Tower the river follows the Missouri bluffs closely for a

long distance, receding from them near Bainbridge, touching again at Cape Girardeau. Here the main Missouri bluff recedes from the river, and appears no more. A short distance below Cape Girardeau a depression allows the Mississippi waters in floods to escape into the swamps, and thence into the Saint Francis. Bluffs again appear on both sides of the river at Cape La Croix, continuing for several miles, and terminating at Commerce, but the bluff on the west is isolated, and apparently has been detached from the Illinois highlands.

Near Commerce the bluffs recede, and the valley expands into the great alluvial basin of the Lower Mississippi.

Throughout the second section the river is, as a rule, held in on one side by rocky bluffs, and is remarkably direct in its general course; only when it leaves the bluffs, as noted, does it work out the long, sweeping curves to be expected in great rivers.

Below the junction of the Missouri and Mississippi the waters of the two rivers flow for many miles side by side with a distinct line of division. As far down as Carondelet, muddy water from the Missouri may be dipped on one side of a boat, and the comparatively clear water of the Upper Mississippi from the other. Long after the line of division is lost to the eye, the difference in the water obtained from different sides of the stream is strongly marked.

The river receives in this section two tributaries of considerable size, the Meramec from Missouri, and the Kaskaskia from Illinois. But their contributions to the volume are too small at low stages to have much practical influence upon the navigation, and but little upon the improvement of that navigation. The contributions of sediment, though considerable at times, are usually so small, compared with the immense quantities brought in by the Missouri, and excavated by the river itself from its banks and bed, that its effect is not discoverable.

The valley throughout this section, except near Grand Tower and at the Grand Chain, is from three to eight miles in width. Nearly the whole of this area is subject to overflow in time of floods. The ground generally slopes back from the river to the sloughs and lagoons with which the bottom is interspersed; and, as in like manner the ground slopes from the farther bank of the slough or lagoon, the probability that these lagoons have at some time been channels carrying large volumes of water is established. Many think it proves them to be sites of old beds of the river, a conclusion which is possible but not necessary, since any considerable volume of water, escaping over the banks of a minor channel, would explain the terraced formation which characterizes these river-bottoms.

The third section, extending from Commerce to the mouth of the Ohio, a distance of thirty-seven and a half miles, derives its distinguishing characteristics from the entrance into the alluvial region, where the uniform texture of the soil allows the river to shape its course without restriction; and, secondly, from the influence of the Ohio.

The times of flood of the Ohio and Mississippi are very different; and as the Ohio alone is able to cause a rise to a stage 40 feet above low water, when the Mississippi is comparatively low, the phenomena of back-water are of frequent occurrence, and its ordinary influence extends as far as Commerce, frequently farther. When the Ohio is high and the Mississippi low, the current through this section is slack, but when the conditions are reversed the current becomes very rapid. Owing, in a great measure, to these excessive changes of velocity, the channel is very unstable and the erosions extensive, as also the accretions.

The foregoing are the principal distinctive features of the sections as they present themselves to the eye.

It must not be understood that the description above refers to the navigable channel, when the river is spoken of as following the bluffs, or in stating that the course of the river is remarkably direct. The bed of the river is so broad that the channel meanders from side to side within the bed just as the bed itself meanders in the valley from bluff to bluff, and as by erosions and deposits the bed of the river, in long periods of time, traverses the valley, so the channel traverses the bed from bank to bank, justifying the remark often heard, that "not a square rod of the bed could be pointed out that had not, at some time, been covered by the track of steamboats."

The movement of the bed is ordinarily so slow that the impression to a casual observer would be that, as a general rule, the changes of the river were comparatively slight and of no great importance, as they do not, within short periods, so completely alter the contour of the bends and reaches as to attract notice. Local observers, on the other hand, noting the disappearance of landmarks, realize that the changes are great, and, keeping no exact record, naturally take an exaggerated idea of the extent and rapidity of the changes.

The shifting of the navigable channel is continual, sometimes in progressive movement; often in sudden leaps; the water forsaking one course and cutting out a new channel, in a very different direction, with very little warning.

The unstable character of the bars and channels renders it impracticable to execute surveys and maps giving in detail the hydrography of the river or the exact form of the bars. If, by elaborate survey, these features were determined, by the time the maps could be executed the changes would be so great as to render them useless for any practical purpose. For this reason maps, descriptions, and plans relating to the Mississippi must of necessity be confined to general features; details would tend to confuse and deceive rather than assist in comprehending the real character of the river, and the mode of dealing with it practically.

The surveys executed under the act of Congress of June 23, 1874, furnished only part of the material for the construction of the maps submitted herewith, and could not do more because of the limited amount of the appropriation. The map from Alton to the mouth of the Meramec is constructed from surveys made in 1870, 1871, and 1872, and does not show the present river as faithfully as could be desired. Very important changes have taken place at and below the mouth of the Missouri since these surveys were made. Below the Meramec, the shore-lines, at all points where improvements are desirable, were determined by actual survey during the season of 1874. At such parts of the river as are now unobstructed by bars, the shores are taken from the best data of former surveys, corrected by reference to the points established by the triangulation made in 1873 and 1874. Although not strictly accurate in matters of detail, the fixed triangulation-points forbid errors of sufficient importance to vitiate any conclusions that will be drawn from these maps. The small scale of the maps submitted, and the fleeting character of hydrographic features in a silt-bearing river, prevent any attempt to show soundings. A dotted line shows in important localities the channel as it existed at the time the surveys were made, and does not profess to show the channel during the season, nor as it existed at any specified date for the whole length of river shown. A considerable portion of the survey was made when the water was at the mean stage,

another part at a stage approaching low water, but none at extreme low water. Consequently it must be borne in mind that the channel marked out is more direct than a low water channel.

Detail-maps of the several localities have been prepared for special studies of localities.

The surveys already executed afford much valuable information as to what the tendencies of the river are, but do not give any information as to what has been or what will be. It is essential that a continuous series of surveys should be made henceforth, as long as the improvement of the river is incomplete; and it is to be regretted that no surveys were made previous to 1873 which can be made available in the study of the physics and hydraulics of this portion of the Mississippi. Regretting the omission of the collection of data in the past, the neglect of observations and full records now would be inexcusable.

The value of the triangulation lately made in fixing points of reference, by whose aid each special survey can be located in its proper place and relations, and the exact changes of the river indisputably determined, has been very great. The necessity for a triangulation, including the whole valley from bluff to bluff, at an early date, is apparent, to secure and verify the position of points along the river, the greater part of which are liable to destruction.

In addition to surveys, as ordinarily understood, full records of observations of stage should be kept, frequent measurements of the discharge made, especially at the extreme stages, and special investigations of the movement of silt, in bodies and in suspension.

Discharge-measurements were made during 1873 and 1874 whenever the surveying-party should find a suitable place and opportunity to take the necessary observations without too great sacrifice of other duties. The series is short, and observations were never taken twice in the same locality; consequently the results must not be considered final nor the conclusions indicated as anything more than approximations.

Table of approximate discharges, &c.

Number.	Localities.	Elevation of water above low water.	Date of observation.	Sectional area.	Width.	Mean depth.	Mean mid-depth velocity per second.	Discharge.	Remarks.
		Feet.		*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Cu. feet.*	
1	Below foot of Carroll's Island.	21. 8	May 17, 1873	73, 664	2, 500	29. 4	5. 005	368, 747	
2	Brickey's mill	19. 6	July 23 and 24, 1873.	54, 152	1, 850	20. 9	5. 209	282, 108	
3	One mile above mouth of Ohio River.	14. 54	July 13, 1874	39, 508	2, 425	16. 3	5. 13	202, 524	River rising 0.2 ft. in 24 hours.
4	Philadelphia Point...	11. 75	June 5 and 6, 1874.	42, 187	3, 740	11. 2	3. 51	148, 103	River falling 0.5 ft. in 24 hours.
5	Three-quarters mile above Chester.	10. 25	Aug. 23, 1873	26, 912	1, 740	15. 5	3. 69	99, 312	River falling 0.18 ft. in 24 hours.
6	Near foot of Arsenal Island.	6. 0	Dec. 4 and 5, 1874.	26, 281	2, 500	10. 5	2. 80	72, 487	River falling 0.25 ft. in 24 hours.
7	Cape Girardeau.....	6. 9	Oct. 23 and 24, 1873.	20, 756	1, 730	12. 0	3. 44	71, 413	River falling 0.2 ft. in 24 hours.

None of these measurements affording an extreme low-water discharge between the mouths of the Ohio and Missouri Rivers, we are compelled to deduce it approximately from the observations made at compara-

tively low stages. Referring to the table and comparing the two observations numbered 6 and 7, when the stages of water were, respectively, 6 feet and 6.9 feet above low water, it will be observed that the amount of the first was 72,487 cubic feet, and that of the latter 71,413 cubic feet, the former exceeding the latter by 1,074 cubic feet, although taken apparently at a lower stage of water.

Accepting these results as approximately correct, they suggest the fact that the bottom rises and falls to a certain extent as well as the water-surface; hence, it is not possible, having a true cross-section at one stage of water, and knowing the velocities at much lower stages, to obtain a discharge for those stages by making the proper reduction in depth and corresponding reduction of sectional area; for the area may be lessened by deposits or increased by the scour during the interval.

Now, if a section of river could be found having an unchanging bottom, by the proper reduction of cross-section to the low-water stage, we might be able to obtain an approximate discharge for extreme low water. This condition is approximately fulfilled at the Chester section, where the bed of the channel proper is solid rock. The proper reduction being made, the sectional area becomes 14,986 square feet.

The velocity at this section for a low-water discharge is arrived at in the following manner:

Comparison of the stages of water when the Cape Girardeau and Chester discharges were taken, shows that there is an apparent difference of elevation of 3.35 feet. The Chester section reduced to this stage gives a sectional area of 21,805 square feet. Comparing this area with that obtained at Cape Girardeau, by observation it was found to be 1,049 square feet in excess. Now, since this area obtained by reduction is greater than that obtained by observation, the velocity must be less at Chester than at Cape Girardeau. Dividing the discharge obtained by observation by the sectional area obtained by reduction, we obtain for a velocity at this stage (6.9 above low water) 3.28 feet per second. Assuming that this velocity continues to diminish in the same ratio $\frac{(V-V')(d'-d'')}{d-d'} = V'-V''$ to a low-water stage, we obtain 2.44 feet per second as the velocity for a low-water discharge at the Chester section.

We now have the probable low-water area, 14,986 square feet; and the probable low-water velocity, 2.44 feet per second; their product, 36,565 cubic feet, is the probable low-water discharge. We can now assume any mean depth of water as a minimum; 10 feet would probably be most desirable. By using this depth (or any other desired) and the low-water discharge as constants, we can ascertain the proper width of water-way at different localities where different velocities exist.

The following table is presented as an application of this:

Discharge ÷	velocity =	sectional area ÷	mean depth =	width water-way.
36,565	2 feet per second.	18,282	10 feet.	1,828 feet.
36,565	3 feet per second.	12,188	10 feet.	1,218 feet.
36,565	4 feet per second.	9,141	10 feet.	914 feet.

The fallacy in the reasoning by which the above conclusion is reached lies chiefly in the assumption that a stage of 6.9 feet above low-water at one point corresponds to the same stage at a point seventy miles distant. The exact low-water reference being unknown as yet at the locali-

ties where these discharges were taken, the conclusions reached are far from satisfactory, but are the best approximations now available.

No observations having been made during an extreme high-water stage, no data exist for determining the proper width between outer levees; therefore no attempt can be made to determine this until more extensive observations have been made bearing on the subject.

From such observations as are on record, it is believed that at a bank-full stage, about 25 feet above low water, 3,500 feet is the proper approximate width.

The unstable character of the Mississippi has its origin in the rapidity of the currents, the excessive variations of volume, and in the loose texture of the soil through which the river works its way. Since none of these causes of instability can be changed or modified essentially, it is necessary to accept this character as an absolute condition, and study its phenomena, in order to gain acquaintance with the laws or generalized facts, and thus be able to obtain the assistance of nature's forces, rather than contend against them.

Soundings, taken at various times and localities, prove conclusively that the depth of water in the river does not follow the rise and fall of the surface as given by gauge-readings. While one would not be justified in asserting it as a fact universally, it is abundantly proven that the bars, at least, rise and fall with the water to a degree that can best be expressed in the statement that a wave of sand accompanies the wave of water in a rise, but moving at a slower rate.

If a cross-section of the river be taken during high water, the soundings, reduced by the known height of the surface above low water, will become zero, or even a minus quantity in many sections, and always much smaller than the depth known to exist at the same locality at low stages.

Again, comparing the depth at various low stages upon the same bar, it will be found that the depth upon the bar does not increase or diminish in the same ratio as the water rises or falls, but, contrary to what would be expected, the depth often increases as the river falls, and diminishes as the water rises on the gauge. In the language of boatmen, the bars "cut out" in a falling and "flatten out" in a rising river.

Since we know that, at ordinary high waters, the low-water channels are completely filled with sand, or very nearly so, the question is suggested whether in great floods the same is not true in a greater degree; in other words, whether a considerable part of the ordinary river-bed is not occupied by sand instead of water? If this be so—and facts, so far as observed, indicate that it is—the height reached by floods depends upon the amount of sand accumulated in the bed as much as upon the volume of water passing; and, moreover, it becomes probable that the influence of tributaries, in raising the river, often exceeds the ratio of the volume of water they contribute. As they come in at times very highly charged with sediment, especially the Missouri, a portion of this sediment is deposited, occupying and obstructing the water-way. The remainder, borne along mingled with the waters, and thus diminishing their fluidity, and therefore the velocity of the flow, also assists in the heaping up of the waters.

At first thought the discussion of flood-phenomena may not seem pertinent to the subject of improving the channel. Since navigation is not impeded at floods, many hold to the opinion that, so far as navigation is concerned, the river at its higher stages may be left to itself, and that

practical operations for improvement should be limited to the low-water bed, and look only to deepening the water over the bars.

But if the sand-wave fills the ordinary bed at times of flood to any great extent, there is reason to apprehend that an entirely new channel may be made, flanking the works of improvement, and disturbing the channel above and below for considerable distances. Moreover, there must always be a period, during the decline from a flood-stage, when the channel maintained by the flood must change, to adapt itself to the diminished volume; for the floods, following the straightest cuts and along the shortest lines, convey the heavier and harder materials with them. The low-water volume, small in quantity and possessing less power, generally works its way through the softer portions of the bed along the bends, &c.

The shifting of the channel, due to the varying volume of water, is a fact observable in all rivers, and the Mississippi differs only in that the changes are more radical. During this transition period, the channel must be uncertain and comparatively shoal; and the only remedy is to control the flow at all stages, at least to the extent of keeping the permanent low-water channel within the width of the channel at ordinary high water. As the high-water channel is always much wider than the low, this would seem to be practicable, the main difficulty arising from the fact that the low-water channel is much more tortuous than the high.

Considered as to hydrography and the direction of the currents, the Mississippi, when low, is not the same river as when high, and obviously the problem of a permanent and complete improvement involves the reconciliation of these diversities.

The bars in the Mississippi are chiefly composed of movable sand, and travel down stream at a rate in proportion to the velocity of the current, changing their shape as they pass the bends of the river or meet with obstructions that lessen the velocity, or deflect the current from its natural direction.

These bars overlap each other so that a longitudinal section of the river-bed would show inequalities similar to the surface of a shingle-roof, as shown by the full lines in Fig. 1.

The dotted line shows the changes that are constantly taking place in the surface of the bars. The material from *a a a* is deposited in the dead angle *b b b*, the bars preserving substantially their shape, but traveling down stream. A plan of sand-bars upon a perfectly straight reach of river, which presents a cross-section approximating the trapezoidal form, the crest of the bar being the highest about midway between banks, is shown in Fig. 2.

Of course we do not find this regularity in all parts of the river. In fact, if it were possible to make the river perfectly straight, it would not long remain so, unless the banks were protected from erosion.

We usually find reaches, which are straight in general direction, broken up into very short curves and approaching the form presented at well-defined curves, as shown in Fig. 3.

The introduction of any foreign substance, such as snags, drift-piles, &c., will change materially the shape and movement of the bars; so also will the curves of the banks. When the river rises the movement of the bars is more rapid, and as the bottom of the river also rises and falls again with the water, a channel is then formed in a new place as the water recedes, the crest of the bar giving way at its lowest point, which is usually nearest the shore, generally leaving a pool of water

below each bar, and the low-water channel winding from side to side under the crests of the bars and through the pools.

Fig. 1.

Fig. 2.

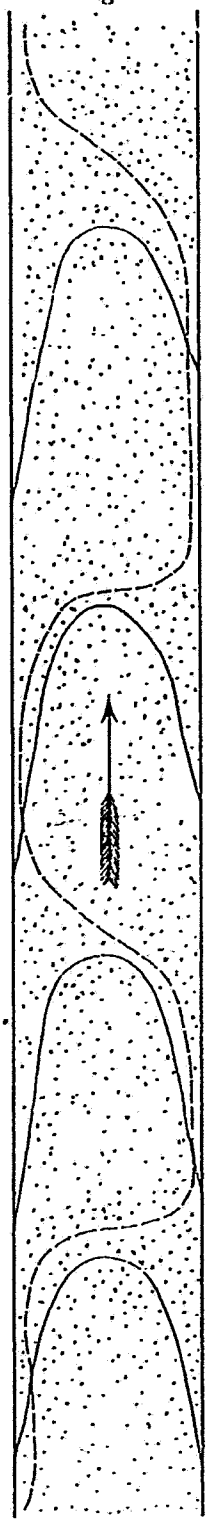
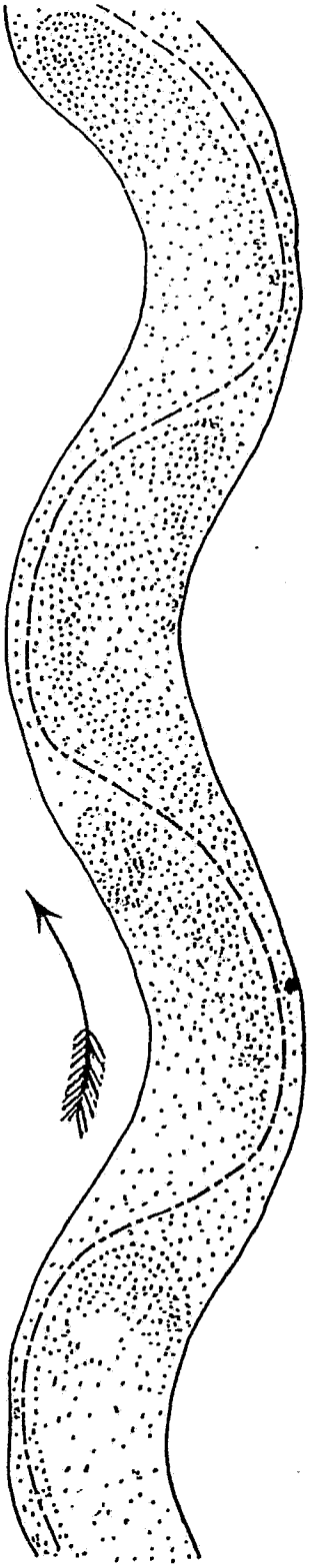


Fig. 3.



The foregoing is given as a generalized statement of the form of the bars, and suggests that the position of the bars is determined by the outline of the banks. The frequent apparent exceptions found in the Mississippi are reconcilable by keeping in mind a distinction between the banks of the low-water river and those of the river at high stages. The dry bars form secondary banks at low stages, and to these banks the extreme low-water channels conform.

It is a fact well known that in the case of rivers flowing through alluvion the channel follows a succession of curves, convex connecting with concave, and that the deepest water generally follows the concave bank. The steamboat-crossings are along diagonal lines, running from near the lowest point of one concavity to a point above the apex of its alternate opposite concavity.

From some observations made upon the Garonne, the point of deepest water in a bend was found to be several hundred feet below the apex of the curve, and the shoalest water along a convexity, at about the same distance below its apex; even where bounded by rocky banks, this effort at curvatures is apparent. Two instances of it may be pointed out, viz: at Cape Cinq Homme, where the right-hand bluff above the point is slightly concave toward the river. The channel, following this bluff closely, makes, after passing the point, a reverse curve of considerably smaller radius, evidently limited to this degree by the rocky Fountain Bluff. At Cape La Croix the case is still analogous, though the channel curves sharply round the point and straightens down to the Grand Chain.

Even in rivers flowing through alluvial beds, the apparent anomaly of the channel being found directly under the point occasionally obtains, and can be explained by the fact that the velocity carries the gravel and other hard materials past the point, the inertia of the moving mass being so great as to keep it in its direct path until arrested by the opposite shore.

The channel through the section between Commerce and the mouth of the Ohio is subject to greater variations than the other sections because the soil is more uniformly alluvial, and the variations of velocity very great. As already stated, the current is slack when the Ohio is relatively higher than the Mississippi; at such times much of the sediment brought to this section must necessarily be deposited by the comparatively still water; to be removed in whole or in part when, the conditions being reversed, the current through this section becomes more rapid than at any other part of the river. The changes consequent upon these variations of velocity differ in degree only from those occurring in other sections, and will require greater care and expense, in any works for its improvement, than elsewhere, but there is no reason to doubt that success can be assured in the application of the same general system.

The banks of alluvion in all the sections are light and movable, with strata of quicksand underlying or outeropping in many places. These banks are constantly changing from the action of the currents upon them. In addition, the water, when high, saturates the bank, while, at the same time, it aids in supporting it. As the water falls, the saturated earth, under its increased weight, and its tenacity lessened by saturation, falls off in large masses, and is taken up by the current. The quicksand, semi-fluid as it is, when it moves laterally, removes the support of the superincumbent mass, another cause of slides.

Another potent cause of action upon the banks comes from the waves of passing steamers, and their action has been found energetic enough

to affect the bank, even when revetted with stone, the wave-action being propagated through the interstices of the revetment-stone.

At what depth the bed-rock underlies the sand, gravel, &c., of the river is only known for a few places where borings have been made. But the question cannot have much practical bearing, since the depth to the rock is usually so great as to forbid the idea of seeking rock-foundations.

The transportation of sediment by running water is a topic that has been often discussed, and many theories advanced to explain the facts. The discrepancies of the theories even now held by different writers is proof that the facts have not been collected and studied to a degree justifying any statement being put forward as absolute truth.

It is recognized that the power to abrade and transport is related to the velocity; also to the character of material. Besides these obvious elements there are others—continuity and change of direction and depth—which have an undoubted influence; but the relative power of each element in producing the result is wholly undetermined; nor is it certainly known whether all the elements have been discovered.

A shade of the truth probably pervades all the theories, but mixed with much error, arising from their having been based upon the study of a single stream, and that presenting probably extreme conditions. From France comes the theory of the controlling influence of breaks in the continuity of the direction or in the changes of direction; from India, the theory that water, flowing between banks or over beds of loose material, carries a load of sediment, bearing a fixed ratio to the velocity, subject to modifications by depth, and, of course, the character of the material carried. Briefly stated, in a river flowing in a bed whose material is uniform, the amount of sediment borne varies directly as the velocity and inversely as the depth; and that the water passing any section is always charged with the full amount of matter which it is capable of carrying. Consequently, the load borne varies with every change of velocity, however slight; dropping a portion of the load when velocity is diminished from any cause producing sand-bars, and recovering its load by attack on the bottom or banks when the velocity increases resulting in erosions; while with a uniform velocity, neither erosion nor deposit can take place. According to this theory, uniform motion, with its attendant saturation with sediment, should be the object.

According to the impact and friction or change of direction theory, deposits are inevitable if sediment is borne, and erosions must occur if the angle of impact exceeds a limit proportioned to the resisting power of the soil; consequently, according to this theory, the object is to diminish the amount of material in motion, to prevent deposits, and to check erosions by protecting the banks exposed to attack, and to prevent the occasion for injurious action by securing an unbroken continuity to direction, and reduction of the angle of impact by regulating the outline of banks to a succession of osculating curves.

Experience has shown that practice under the latter theory is attended with success. The former theory rests upon observations, but has not been tested by practical works for the improvement of rivers based upon the principles given. One prominent fact observable on the Mississippi is contradictory of the practical part of the equilibrium or India theory, for, as has already been stated, the waters of the Mississippi and Missouri Rivers flow side by side for many miles, with a distinct line of division between clear and muddy waters. Where the waters of these rivers first come in contact, the clear water of the Mississippi is pressed

against the alluvial bank on the Illinois side, which it cuts into rapidly, and in the clear part of the river is found the deepest water and most rapid current. Passing into Sawyer Bend, on the Missouri side, the Missouri water comes in contact with a bank similar to that previously pressed by the Mississippi waters, and, although thick with sediment, the erosion at this place fully equals that above; continuing past the city of Saint Louis, the water comes to the bridge with the line of division yet distinct, and immediately below the clear Mississippi water presses upon a bar upon the Illinois side without any remarkable attack. Thus it may be traced until the difference in the waters fades out, but without developing anywhere the marked erosions of the Illinois bank, or the alternative extensive deposits on the Missouri side which the theory would demand; for, according to it, it should be impossible for two neighboring fillets of water to flow over the same bed, and with equal velocities, without carrying an equal load. The case has been traced so far that each kind of water has undergone both increase and diminution of velocity, and many changes of depth and direction.

Many facts are required to establish a theory; one, if unreconciled, can disprove it. When the attention of the author of this theory was called to the fact here presented, he replied:

* * * In the examples of the large American rivers you refer to, where the Missouri brings down water quite turbid, while the Mississippi is nearly a clear stream, I would observe that, where the load of solid matter held in suspension is not probably the one-thousandth part of the weight of the water flowing down, it may be practically impossible to observe any retarding of the velocity on account of the load transported; but with such torrents as above described,* bringing down a large percentage of solid matter, and with water loaded with sewage, I believe it is possible by experiment to discover a difference in the velocities, as compared with pure water with the same slope and transverse section.

The examples above given of water flowing at great velocities pitching about bowlders shows that a certain power must be exerted which offers some resistance to the flow of the water, and if so with rocks or bowlders forced to bound forward, so with shingle, sand, or the finest particles of clay will the flow of every stream be somewhat retarded in some proportion, due to the quantity and quality of the load transported. In the case of the Missouri River, I believe that it will be found that the rock and soil of which its catchment basin consists is composed of materials that have already undergone the abrasion of water, while that of the Mississippi will be found more crystalline, and sand will predominate instead of mud. In proof of the power of flowing water picking up its load, I may here state that in the cold season the water is quite clear, and a rupee can be seen at depths exceeding 10 feet at the head of the Ganges Canal; at the sixth mile the rupee is lost sight of at 5 feet below the surface; at the twelfth mile, about 4 feet; at 3 feet depth the rupee can be seen some twenty miles down the canal; and so on did the muddiness of the water go on increasing till about the fortieth mile, when a saturated load of solid matter was attained. It was therefore in these first forty miles that all serious action on the canal bed and banks took place prior to the time I held up the surface of the water at the falls; and in my report of November, 1861, I estimated the cutting that had then taken place in the first forty miles at some eighty or ninety millions of cubic feet of earth. It was by observing this cutting in the upper portions of the canal, and the tendency of the stream to change its channel lower down, which led me to think of this abrading and transporting power of water; and it was my native foreman, Sahib Sing, who first drew my attention to the fact that this abrading action on the bed only took place when the water admitted into the canal was comparatively clear, and not when the Ganges was in flood, passing down turbid water, which can only be compared to pea-soup, for nearly six months in the year.

The writer of the above, in dwelling upon the turbidness of the water in question, seems to have lost sight of the fact, or at least does not seem to attach much importance to it, that large quantities of matter may be held in solution, the capacity for which varies with different soils; also, of the fact that the capacity of a stream to abrade is mainly due to its living force, ($M V^2$,) a function of its mass and velocity; and

* Certain mountain-torrents in India, here referred to.

that the factors may change and the product remain the same. The resistance to abrasion depends upon the nature and shape of the banks and bottom. The matter becomes complicated when taken up in this shape; and while Mr. Login's statement of facts is entitled to full respect and belief for the locality to which he refers, it does not follow, by any means, that the theory is applicable to the Mississippi River.

In the first part of the foregoing extract Mr. Login is defending the proposition that the transportation of sediment, being work, must be at the expense of force, and, in the case of running water, gravity being the moving force, its expenditure must diminish the velocity. Whether this be accepted, or the view taken that mixture of foreign matter diminishes the fluidity of the water, is practically immaterial; the velocity would be less in either case than for pure water, though, as he says, the effect would be inappreciable except in extreme cases. The proportion of sediment in this part of the Mississippi River under discussion has been stated, in a report made to the public-school board of Saint Louis, to be $\frac{1}{3220}$ part in volume. Noting that Mr. Login likens the sediment-saturated waters he observed to pea-soup, and remembering that his idea of pea-soup is English, it is evident that the waters of the Mississippi do not approach such saturation; consequently, the theory does not apply practically to the Mississippi.

Mr. Login's observations show that the point of saturation is sometimes reached; and he does not assert that water flowing over an unstable soil is always so saturated; rather the contrary; for he says that it required the active erosion for a distance of forty miles in the Ganges Canal before the point of saturation was reached. The violent and unwarranted assumption that a given current is always charged with the full load of solid matter that it is able to carry has been added to his statement, and is abundantly disproven.

Passing from theory to the practical question of securing the object definitely placed before us by the order of Congress requiring this survey to be made, which was to obtain plans and estimates for the improvement of the Mississippi, so as to secure a navigation affording a depth of at least 6 feet, at the lowest stages of water, from the mouth of the Illinois to Saint Louis, and 8 feet from Saint Louis to the mouth of the Ohio, the first inquiry is concerning the character of the navigation desired. Since the requirement specifies the lowest stages of water, it must be understood that the same or a greater depth is expected at all stages above the lowest. The lowest stage known does not occur when navigation is practicable in the section of river under consideration, being a consequence of ice-gorges above the point of observation, acting as dams in cutting off for a time the supply of water to the river below, which, therefore, drains out. Such abnormal occurrences cannot be provided against.

Taking the lowest stage to mean the lowest occurring when navigation is not suspended by the rigor of the season, the obtaining of the depths specified at that stage does not necessarily imply the existence of that or a greater depth at all higher stages; for, as has already been stated, the channel-depth sometimes increases as the river falls.

The depth of a river depends upon the form as well as upon the area of cross-section, and a large area may, from immoderate width, afford less depth than a smaller but narrower section—a consideration of great importance in determining the plan of improvement.

Another requirement of improved navigation is, that it should be reliable. The possibility that an improved navigation, after being available for one or more seasons, may deteriorate, would forbid the invest-

ment of capital in floating stock and the other facilities requisite to the transaction of business. Commercial relations are so extended and delicate, that an inferior and more costly route of transportation will be preferred to one having the advantage in these respects, but which cannot be relied on for future engagements. This quality being in some degree wanting in the Mississippi route, is one of the principal reasons why the business of transportation upon this route has not kept pace with the development of the territory it drains.

The demand, then, is, first, that a good navigation be obtained; second, that it be maintained.

The magnitude of the river and of the interests at stake, which occasion the demand for its improvement, measure, the one the task, the other the means of accomplishing it. How great these are, it is not the design here to consider; but it is assumed that they are in due proportion, and that the only questions before an engineer are, what can be done, the plan of operations, and the mode of conducting these operations.

The first demand, that a good navigation be obtained, is satisfied with depth of channel. Combined with the second, that it be maintained, the continued existence of the channel is required, or the provision of ample and efficient means for its restoration, whenever impaired, so quickly, that practically no interruption shall occur. The first alternative implies permanent works; the latter may be satisfied by temporary.

Many persons, as before adverted to, hold to the opinion that attention should be confined to the amelioration of the low-water channel, as it defines itself year by year. Therefore, a consideration of the various modes of effecting a temporary benefit is necessary to a fair discussion of the subject before us.

The effort for this purpose must be directed to opening a passage through each bar as required, and as the bars, or reefs, are comparatively short in the direction of the channel, it is supposed that all that is needed is to make through the crest of the reef an opening wide enough for navigation, and that the increased strength of current will keep it open for the remainder of the low-water season. If it were possible to consider the reefs as abiding in nearly the same position throughout a season, this mode of opening a channel would be simple and apparently easy; as the appliances used, after accomplishing the end at one locality, could be moved to another, and thus, in succession, a single equipment would answer for a considerable extent of river. But as the sand-reefs have a progressive motion in many cases, oblique to the line of deepest water, the channel is crowded out of its first position, and a new crest is formed, a process which can repeat itself many times in a season. This tendency, in connection with the shifting of the channel already mentioned, as attending decrease of volume, will make frequent returns of the equipment to the same locality necessary, and instead of maintaining a good navigation over a long extent, it will be found in practice, that, to be effective, an equipment would find full employment upon two or three crossings, and while an opening is being made the appliances must occupy the channel; which is a serious objection. In order that these opened passages may maintain themselves, it is necessary that the additional area obtained in the channel should be compensated by the filling, or obstructing, of an equivalent area from some other part of the cross-section, outside of the channel; otherwise, we expect the impossibility that a certain volume with unchanged or increased velocity, should fill an increased area.

These remarks apply with equal pertinence to two classes of appliances, viz, scraping, dredging, or agitating machinery, and portable dams. Comparing the merits of these classes of devices, the advantage would be in favor of portable dams in first cost and operating expenses. Both classes have been tried, and have demonstrated their ability to open a way through a reef; but the results have not been satisfactory, hitherto, because not lasting. It may be objected to this statement, that the permanency of channels opened by portable dams has not been tested, as the only extended series of experiments on the plan of opening bars has been with the Long scraper; but it must be admitted that the permanence of an opened channel cannot depend upon the means by which the opening was made when the means are removed from the scene. The competition between devices for this purpose is limited to cost and efficiency in opening, and it is not the purpose here to discuss the relative merits of devices, but to consider the results which may be attained by their use. Experience indicates that to maintain a channel in this way would require an equipment for each section of 10 miles; to be kept in active operation during the low-water season of each year for all time; and the results then uncertain, and a serious disadvantage attending the application of the system.

A permanent improvement must of necessity be designed and executed in entire harmony with the natural laws of the river. A mighty river is impatient under restraint—can be led, but not driven. In one sense, the difficulty of executing a plan of improvement increases much more rapidly than the size of the stream; in another sense, the potent forces, judiciously handled, can be made to do no inconsiderable part of the work.

Permanent works may be considered as serving a twofold purpose: first, to obtain and maintain a good navigable channel; second, to protect the adjacent lands from erosion and overflow. The navigation interest is without question the only one now to be considered; but the landed interest will certainly derive important incidental advantages from the permanent improvement of the channel.

The maintenance of a good navigable channel requires—

1st. Sufficient depth at all stages.
2d. A judicious location.
3d. Stability in position.
4th. Facility of approach to landings.
5th. Easy changes of direction.
6th. Moderate velocity of current.

These requirements stand above in the order of their importance. The first is a condition-precedent, and must be satisfied. In solving the problem of securing depth of water, we have to deal with certain elements, all to some degree variable, either naturally or artificially, and the combination of the whole fixes the depth at any given time and place. These elements are width, volume, and velocity; and the latter term depends upon the slope or descent, and distance, as its controlling elements. Of the terms of this function the slope is fixed naturally, if we compare the elevations of geographical points connected by fixed lines; but if the length of the lines can be varied, then to that extent slope is an element subject to control; also the same result may be reached by producing a different distribution of the fall. To deepen a channel, by changing its slope, would be equivalent to lengthening the river. (The change of distribution of fall involves its concentration by dams, a method clearly inapplicable to a large silt-bearing river.)

Volume is an element which, for periods of time, is fixed naturally;

but the discharge may be distributed artificially, so as to be more nearly uniform than the supply. The proposition to feed rivers at low stages, from reservoirs filled at the higher, is practicable with small streams, but for large rivers, the areas required for reservoirs, and the cost of retaining-dams, become so enormous as to render the proposition impracticable.

The element of width is so evidently within the range of control, that no argument is required to establish the position, that contraction of widths is the easiest and most practicable mode of increasing the depth of channel in all cases where the volume is practically beyond our ability to control; in some cases, in addition to contracting width, it would be advisable to lengthen the channel. It will be seen that shortening must be avoided, as a rule; for the effect of a shortened course is to increase the slope and velocity, which would require an inordinate contraction of width to obtain the desired depth, and the increased velocity would endanger stability.

The second requirement, the judicious location of the improved channel, includes the purely engineering consideration of following the natural tendencies of the river, or at least the negative proposition, that no unnatural changes of position should be made, or unstable natural conditions be accepted; and also due consideration of the convenient use of the channel for all the purposes incident to navigation and commerce.

In the consideration of this topic, we come in contact with many local and individual interests; also, with the opinions of many persons who have from observation and reflection arrived at fixed opinion concerning the course to be followed. Conflict with the former is to be avoided as far as possible. The latter may be considered, but cannot be allowed to govern. There are two opinions (held by many who glory in calling themselves practical men, and delight to cast contempt upon what they call scientific theories,) which have their foundation in very poor theory, because unscientific. One is that the channel should be straightened and canalized; the other, that it should, in all cases, be held along the foot of the bluffs, where such exist. Without entering into any extended discussion here, it is proper to recognize the existence of these opinions, and state briefly why they must be rejected.

The logical objection to straightening the channel has already been given—the velocity would be increased thereby, and increased destructive energy be brought to bear upon the banks and bed. It may be said that such increase of velocity would be temporary, as the river would adapt itself to the new condition, and, in time, regain its former slope. This can only be done by regaining its original length, or by a lowering of the bed, proceeding from the lower part of the river toward the upper. But where the bed is composed of material too hard to be readily moved, the accumulated fall must produce a rapid. The cut-offs that have taken place in the Lower Mississippi have not permanently shortened its course, and many which were made in Europe, especially upon the Rhine and Danube, with the purpose of shortening the distance between points of commercial importance, have defeated that design, by creating a current which proves a serious obstacle to ascending boats; and the lowering of the level in the reaches above the cut-off develops many new obstructions, while the deposits in the pool below cause similar difficulties there. The idea of the advocates of straightening is that, with a shorter course, flood-waters will pass without entailing injury, and that the increase of current will not impede steam-

navigation in a greater ratio than would be compensated by the decrease of distance.

The suggestion that the channel should be made to follow the bluff, is made simply because the bluff presents an unyielding bank, against which it is supposed to be an easy task to hold the current. As the bluff-lines are very straight, this proposition is similar to the first-mentioned, and liable to the same objections. To hold the river to straight lines would be a work of great difficulty, and the difficulty would increase with increased velocity. One fear entertained by those favoring the bluff-line is, that if the channel be allowed to make a sweep out into the bottom, it cannot be controlled, forgetting that it is easier to control a current following its natural course through alluvial soils than it would be to force it from that course by works which must rest on the same unstable foundation as the lighter structures required to restrain it within reasonable bounds. Another consideration, which would be fatal alike to both propositions, arises from the disturbance of existing business relations by the destruction of landings, which must result from their adoption. Moreover, if the bluff is followed, the landings would be chiefly limited to the side whose broken character forbids the expectation of much agricultural produce being raised; and, in any case, the landing would be difficult of access from the back country. In addition, the opposite alluvial side would be cut off from access to deep water almost entirely.

Existing business relations have adapted themselves to the natural course of the channel; and, in order to avoid individual claims for compensation, it will be necessary to make the improved channel follow the natural course as far as possible, on the principle that riparian rights and benefits, which have been destroyed or changed by the action of natural causes, furnish no ground of claim in equity, if the privation be rendered permanent.

Policy, then, would determine the advisability of following the existing channel in all cases, and the same course would logically follow from a train of scientific reasoning, for the law of a stream is the expression in general terms of the facts presented in nature, and is necessarily abstract. To reconstruct the stream according to conditions imposed or assumed, can be done successfully if we know all the facts and relations which enter into the problem. The omission of one may be fatal to success; hence all arbitrary changes are to be avoided. But nature overlooks nothing, and we may confidently assume that the position and direction of the river at any time is the resultant of all the forces, and consequently is a concrete expression of the law of the stream, which we may modify and preserve, but may not safely destroy or radically change. To accept and follow nature is, in this case, the beginning and end of science. To attempt either to straighten the river or to compel it to follow the rocky shore would be alike presumptuous.

The third requirement—stability in position—is a natural consequence of permanent improvements, and essential to the establishment of facilities for the traffic. To insure this quality, it is necessary that the velocity should be sufficient to carry the lighter material brought into the channel to a suitable place for deposit, but not great enough to cause erosion of the bank.

The fourth requirement—facility of approach to established landings—is an important consideration, and since large towns cannot follow the river in its changes, the conditions presented are often antagonistic to the natural bent of the channel; and in such cases the demand is absolute that the natural be changed. At times the conditions border upon

the impossible. Take, for instance, the case of a town situated upon the convex bank of a river; it is well-nigh impossible to maintain the channel on the convex side, because unalterable natural laws forbid. If we try to contract the width to such narrow limits as to obtain a required depth on the non-channel side, which is the best, and, indeed, the only thing that can be done, we endanger not only the works themselves, but also the property, and lives even, of the people, when the waters of a mighty flood demand passage through the narrow gate-way; and no safe contraction can assure the desired depth on the convex side. In this connection it may not be out of place to remark that the injudicious acts of individuals, or municipalities, may often endanger the improvements made by the General Government for the benefit of the whole people to serve some local project, and that the establishment of regulations defining riparian rights and the privileges of town authorities is a subject demanding the attention of Congress. The conservancy of navigation being undeniably vested in Congress, the exercise of that power, in defining the limits of encroachment upon navigable waters, is proper and necessary.

The fifth requirement—that changes of direction should be easy—is mainly in the interest of stability, but also has a practical relation to the convenient use of the channels. A discussion of the bearing of the direction of currents in relation to the banks, if entered into, would exceed the limits of this report. The result reached would be, that the current should be parallel with the banks whenever possible, and abrupt changes of direction avoided. Practically, it would not be proposed to make many changes in the present contour of banks by active interference, but rather to secure a favorable alignment when its exists; and when it is imperfect to patiently wait for nature to work out the problem of a good line. Accurate surveys of stable bends will determine the degree of curvature most favorable. When the character of the soil does not furnish sufficient resistance, some form of artificial protection must eventually be resorted to.

During this past season particular pains were taken to survey and delineate upon maps the strongly-developed curves or bends known as Rush Tower, Saint Mary's, and Cape Girardeau, the latter being considered a good example of a curve of stable regimen. These three curves, if carefully studied by means of resurvey for several years, may develop laws, the knowledge of which will be of the greatest importance in conducting the improvements of the river.

Dafontaine, who devoted a number of years to careful study and improvement of the Rhine, expressly said, that the degree of curvature to be given to the bends on a river could only be predicated upon observation of existing curves of known stability on the same stream.

Mahan, in his work on civil engineering, (edition of 1867,) says:

> From observations made upon the Rhine, it is stated that elbows with a radius of curvature of nearly 3,000 yards preserve a fixed regimen; and that the banks of those which have a radius of about 1,500 yards are seldom injured if properly faced.

The fact that the natural course of a river, flowing through an alluvial bed, follows a series of direct and reverse curves, merging into each other, is universally admitted by all engineers of study and observation, and the expediency of maintaining them in such course, where local interests of magnitude do not demand and warrant departure, is equally admitted.

A cross-section in a bend will, generally, approach in shape a right-angled triangle, the right angle at the bottom and near the concave

bank. Consequently, in a bend, the width may be greatly increased beyond that admissible for straight portions of the river, yet maintaining nearly the same area of cross-section, and sufficient depth in the channel. In bends, therefore, protection of banks is the improvement required, and, considering navigation only, the work is by no means urgent.

The sixth and last requirement, moderate velocity, has been discussed incidentally already. There are localities, especially below Commerce, where the velocity is at times excessive, but beyond possibility of being changed for the better. The condition must be accepted and met by stronger works to insure permanence.

Having in the preceding discussion shown that a system of temporary expedients would fail to secure the end, and also defined what a permanent system would accomplish, the question arises, can the superior permanent system be carried out upon such a river as the Mississippi? In answering this question we have the benefit of the experience of European engineers, who have successfully improved silt-bearing rivers traversing alluvial valleys, and subject to great variations of volume, and the Mississippi differs only in degree from some of these successful precedents. That this difference in degree does not present insuperable difficulties, is proven by actual experience in works of the character proposed, executed during the last three years upon the Mississippi, which have proved successful.

The problem, then, is solved as an engineering question; the execution is a question of time and money.

The adoption of the permanent system is but a question of time; for, as the country becomes older and more densely populated, aside from the requirements of navigation, the products of the fertile alluvial lands will be essential to the welfare of the country, and the state reasons which have led to the regulation of European rivers will demand the same for the Mississippi, and, in time, its principal tributaries also. The completion of these works will require many generations; but as the necessity is clearly foreseen, it would be inexcusable to ignore it now, since it is entirely practicable to make every step in the interests of immediate wants a step, also, toward the final end, without adding to the cost or delaying the realization of the benefit desired. Assuming that this course is to be pursued, it remains to consider the steps that come first in the system proposed, which will be the work for the years immediately before us.

In the interest of navigation the improvement of the worst bars is first demanded, and this consideration decides each year the points where work is to be done. As the worst bars now are at or very near islands, or high bars that are as effective as islands in dividing the waters, the most useful work at present is the closing of the chutes, which, we may be confident, will materially help the navigation, as the cases are rare where a serious obstruction occurs when the water all flows in a single channel. After the closing of the chutes, the contraction of width in wide reaches comes as the next step, and, when complete, good navigation is obtained, and must be maintained, by the protection of caving banks.

The closing of chutes often involves more or less conflict with local and proprietary interests, and in some cases with matters which rise into the importance of state questions.

The definition of the boundaries of States by the channel of the Mississippi gives the jurisdiction over islands to the States to which they belonged at the time the boundary was defined, as decided by the

United States Supreme Court in the Wolf Island case, (Missouri *vs.* Kentucky, Wallace's Reports Supreme Court United States, volume 11, pp. 395–411.) Several cases are known where the present channel divides the island from the State to which it belongs, and if the old channel, now but an insignificant chute, is closed, the island will be territorially annexed to a State having no jurisdiction over its soil. It will readily be seen that serious complication may arise in such cases. Such annexations are likely to occur from natural causes, and several will necessarily be made if the improvement continues, and the closing of chutes is to be determined upon engineering considerations alone.

It may not be out of place to mention here the general belief prevalent among owners of land adjacent to island chutes, that the construction of a dam across the chute or slough will insure accretions of land to their benefit.

This is true to some extent. In the case of a single dam, the accretions generally take place in the shape of a bar across the foot of the slough or chute; another in the prolongation of the island; and a deposit at the head of the chute, extending some distance above the dam, frequently neglecting, however, the immediate vicinity of the dam altogether. A high dam just below the level of ordinary sediment-bearing floods would insure more deposit; but experience on the river Rhine, where, in most cases, the object was to make land, demonstrated the fact that three or more dams were generally necessary to insure sufficient depth and extent of deposit. In the case of a single low dam it was found better to locate it at a considerable distance below the head of the chute, in order to allow as much of the gravel and other material to enter the chute as possible, not only to aid in the formation of land, but in addition to prevent the material being swept into the channel.

The formation of land not being an object of present consideration, we may say that as a general rule low dams and dikes should alone be used. In general terms, none of the works erected should interfere with the free discharge at high stages, but should begin to act at some intermediate stage. This should be before the want of depth is felt, and will probably vary for different localities.

The meaning of the words "intermediate stage," in the last paragraph, requires definition. The idea is, that the dikes and dams should be of such height as to produce action upon the bed when the river is first approaching the low stage, so as to prepare the channel, in some degree, for the less powerful effect of the diminished low-water volume. Yet it must not be inferred from this that violent action upon the bed is by any means advocated.

As before stated, the path of the heavy materials of floods is generally along the most direct course. The low water, having to cut for itself a channel, seeks the line of least resistance, through the lighter and softer material, and this is one reason why the low-water channel is, in nature, more tortuous than the high.

Referring to what has been said on the subject of the partial filling of the bed at high water, and the principle universally accepted, that depth of channel is easiest secured by contracting the width, the query arises, is it not possible to retain the high-water deposits in place as the water falls over a part of the width, and thus contract the width at low water? Two modes of accomplishing this suggest themselves: first, to protect the areas which it is desired to convert into dry bars by inclosing them with barriers quickly and cheaply constructed; second, by attacking the crests of the reefs upon the line it is desired to have the low-water channel follow, and thus concentrate the scour upon that part

of the bed which is to be the low-water way. In practice it might be found advisable to combine the two methods, and thus open a field for the use of some of the devices discussed under the head of the temporary system.

If, on trial, these suggestions should be found practicable, the benefits to navigation which would follow a regulation of the river could be more quickly and cheaply attained than in any other way, for we have but to secure the areas laid dry from being washed away, and the opposite bank from caving, to render the improvement permanent. Treated in this way, the immediate and temporary improvement would be entirely consistent with the system of permanent improvement.

The mode of construction having been described in my annual report for the fiscal year ending June 30, 1873, (see Report of the Chief of Engineers, page 444 *et seq.*,) it is not necessary to enter into details here, as in all essential features the plan there discussed is still followed.

Variations in the minor features, of course, must be made, as circumstances demand.

In constructing dikes and dams upon the unstable foundations found in the Mississippi, the difficulties to be encountered are the strength of the current and the liability of scour around and under the works during construction and after completion. The strength of the current is a difficulty to be overcome, and must increase with the progress of the works until they arrive at or near the surface of the water. The scour must be arrested at an early stage of the work, or the additional expense incurred of placing foundations in deep water, and of the greatly increased prism of material required to reach a determined height. Settlement of the works during construction and even after completion is to be expected.

Various modes of construction have been tried and most carefully studied, and decided preference is given to the general plan of brush foundations and riprap superstructures as adapting itself to any shape of bottom, and being able to endure settlement without injury.

Brush foundations, besides flexibility, have the merit of distributing the weight of superstructure over a considerable area, while the body of brush presents, when compacted by the superincumbent weight, small interstices for the passage of water close to the bottom. This material being found in large quantities along the river, can be obtained and handled at moderate cost.

Extended operations would soon exhaust the present supply, and it may be found advisable to encourage the growth. Under moderate appropriations, the natural production would probably suffice.

Material suitable for riprap is obtainable at many points along the river, insuring its procurement at very reasonable rates. It would be good policy for the Government to acquire, by purchase or long lease, several quarries, to be operated under contracts or by hired labor, as may be found most desirable.

In construction the utmost rapidity of progress is essential to economy, and it has been found practicable to carry the foundations across channels and bars so rapidly that no considerable deepening took place as the work advanced, by limiting the first work entirely to putting in an apron to protect the site of the proposed work.

In closing chutes this class of work must be done when the river is at a low stage, and in any case cannot be done when drift is running.

This limits the possibility of preliminary work to the fall season, and renders any loss of the favorable season a serious disadvantage. The postponement of appropriations to the close of the session of Congress

is unfortunate in that every alternate year a considerable part of the season is consumed in preliminaries, a loss which could in a measure be avoided if the amount to be appropriated could be certainly known as early as March of each year.

As already intimated, it is not practicable to present plans in detail, owing to the great changes which must occur between the time reports are made and the commencement of work. In so extensive a field as the Mississippi from the Illinois to the Ohio the simultaneous prosecution of works at all the points where improvement is desirable is not possible under the system of yearly appropriations, but might be done if the full amount estimated were granted at once. As this course is not supposed to be possible, it is contemplated to prosecute the works in the order of their importance to navigation, selecting those places which present the most formidable obstructions for the first operations, the number undertaken each year depending upon the extent of work required at the several places and the means available.

The estimate of this report is based upon the present condition of the river. It is probable that some of the items included in the estimate will be found unnecessary, the desired end being reached naturally; others not estimated will as probably be found necessary; it is, therefore, thought best to name the aggregate sum for each locality, without specifying the items of the estimate. As the estimates are made upon the basis that certain lengths of dams and dikes will be required, and at a cost per unit, taken from the actual cost of such works already constructed, the aggregate cost will probably not be materially changed by the changes in the position and length of individual proposed works.

The list of localities is not final, if we consider the probability, almost certainty, that new obstructions will be developed hereafter. The estimate given by localities may be taken as the cost of obtaining the navigation desired. To maintain that navigation will require the revetment or other protection of caving banks. The estimated sum of $4,000,000 is intended to cover the cost of such works—to preserve the channel at those points where the necessity is likely to occur.

Further examination would be necessary to determine where works of this character are most needed. The greater part, we may safely say, would be required between Commerce and the Ohio. The estimated time for the execution of the improvement of the channel is four years; the work of maintenance will never be complete.

One million dollars could be judiciously used the coming year, and the appropriation of this sum is recommended. With such an appropriation, work would be continued at Saint Louis Harbor, Horsetail Bar, Turkey and Devil's Islands, and new works commenced at Piasa Island, (above Alton,) Perry's Towhead, Liberty Island, Power's Island, and Greenleaf's, the bars at these localities being the ones which now most seriously obstruct the navigation.

ESTIMATE.

Locality.	Estimated cost.
From the Illinois to the Missouri River	$600,000
From the mouth of the Missouri to Saint Louis	150,000
Upper section of Saint Louis Harbor	185,000
Arsenal Island	100,000
Horsetail Bar	100,000
Twin-Hollow Bar	80,000
Platin Rock	72,000
Selma	110,000
Fort Chartres	75,000
Turkey Island	100,000

Locality.	Estimated cost.
Saint Genevieve	$100,000
Liberty Island	100,000
Hat Island	150,000
Grand Tower	50,000
Hanging-Dog Island	30,000
Moccasin Springs and vicinity	200,000
Devil's Island and vicinity	250,000
Hamburgh	50,000
Commerce and vicinity	200,000
Buffalo Island	20,000
Greenleaf's	150,000
	2,872,000
Add 10 per cent. for contingencies	287,200
Revetment between the mouth of the Missouri and mouth of the Ohio Rivers	4,000,000
Total estimate	7,159,200

In the conduct of operations upon the treacherous foundations which characterize the Mississippi, economy and success demand that the engineer in charge should have entire liberty to modify his plans whenever necessary, and to have full control over his work; to push it forward when occasion demands, and to suspend when it becomes desirable so to do.

Contracting works of this character is attended with serious difficulties: first, because all estimates are necessarily indefinite and uncertain; under varying conditions the character of work is liable to change, in the kind, proportions, and amount of material used, and what was expected to be easy may become difficult, or anticipated difficulties may disappear. These contingencies render it very difficult to frame specifications that will meet the practical conditions, and bids must be made at a venture, which demands a wide margin in prices beyond what a definitely-described work can be done for. Under such conditions the result of a letting, under existing regulations, is almost inevitably to give the award to irresponsible parties, the guarantees and bonds which satisfy the requirements affording no sufficient security. Experience has shown that, with an inefficient or tricky contractor, works of this character are very expensive, for delay or neglect, intentional or not, results alike in vastly-increased quantities of material; and as the plans contemplate the placing of foundations in water of moderate depth, the suspension of work for a few days will produce a local scour that exceeds the depth provided for, and compels resort to more expensive methods not provided for in the contract.

Considering the matter in the light of experience, I cannot recommend the contract system, so far as the preliminary work of aprons and foundations is concerned. After these preliminaries are secured there is no objection to adopting the contract system for the delivery of material in the body of a dike or dam. Necessity has compelled me to provide the plant required for the construction of these advance works, and, working under small appropriations, this plant suffices to do all the work; and, it being unquestionably good policy to keep equipment fully occupied, the work of the present year has been done by the United States directly by hired labor, and the purchase of material in its natural state. Although compelled, by act of Congress, to pay twenty-five per cent. advance upon prevailing rates of wages for labor, the results show no increase of cost over the prices formerly paid contractors for material delivered in place; and all the work and workmen being now in immediate control of the engineer in charge, he is made responsible for the success of his operations.

This system has been found to work well; no serious mishaps have occurred, and the work is done more cheaply than before, though, in part, this may be attributed to improvements in the method and experience in their application. Contrary to the prevailing impression, that faithful labor cannot be obtained from men directly employed by the Government, the amount of work done compares favorably with that accomplished by equal numbers working for a contractor. Faithful labor can be had under faithful overseers and foremen by any employer, and with unfaithfulness or inefficiency in the higher grades no employer can secure faithful service.

To carry on extended operations, such as are contemplated if this project meets the approval of Congress, it would not be practicable to do all the work directly by hired labor, on account of the extensive equipment that would be required at times, but which could not be fully employed at all times; besides, the burden and responsibility of making disbursements in small sums would be excessive. For the reasons stated, I would respectfully recommend that, under annual appropriations of $300,000 or less, the system now practiced, to do the work directly by hired labor, and purchase of materials in open market, including in the latter the privilege of purchasing material delivered in the work when it is to the interest of the Government to do so, be continued. Under appropriations exceeding $300,000, the conduct of all critical and uncertain operations to be by hired labor, and material purchased as above; and the construction of works whose character is ascertainable to be let to contractors.

The plant required to carry out these recommendations, under yearly appropriations of $1,000,000, would consist of two tow-boats, two steam-launches, twenty barges, six pile-drivers, one Osgood dredge, and such small tools as would be required for quarrying and handling stone, and procuring other material employed. Of this plant there is now on hand, owned by the United States, one tow-boat, one steam-launch, sixteen barges, three pile-drivers, and a stock of tools proportionate to the present scale of operations.

RECAPITULATION.

I briefly recapitulate the conclusions reached by the discussion, and which are the basis of my recommendations:

1. Improvement must not only be made, but maintained.
2. Temporary expedients fail to answer the requirements, for want of reliability.
3. Permanent improvements are known to be practicable by actual experience in the case of other rivers similar in character, though of less size, and the practicability of executing permanent works in the Mississippi is demonstrated by works already constructed.
4. In an improvement the natural channel should be followed as a rule.
5. The rights of individuals and municipal or other corporations should be defined, and all proposed works subject to approval by United States authority, as is the case now with bridges.
6. The order of execution of work should be decided with a view to afford the earliest possible relief to navigation at difficult places.
7. Improvemtnt of the channel can be best secured by bringing all the water into a single channel of moderate width; an early step would be the closure of secondary channels at islands and elsewhere; closing

chutes will raise questions of jurisdiction between States, which should be provided for at an early date.

8. A combination of the appliances designed for temporary improvement with permanent works may be practicable, giving earlier results and at less expense. Estimates, however, are made upon the basis of improving by permanent works alone.

9. The estimated cost of improving the Mississippi, so as to afford 6 feet depth in the channel from the Illinois to Saint Louis, and 8 feet from Saint Louis to the Ohio, is $3,159,200; and the estimate for such maintenance-works as can now be foreseen is $4,000,000. The improvement-division of the work can be completed in four years, and the appropriation of $1,000,000 is recommended for the first year.

10. A mixed system of conducting the work is recommended; critical and uncertain operations by the United States directly, and those whose character can be definitely ascertained in advance, by contract.

11. The removal of wrecks and snags from the channel will remain, as heretofore, an important part of the work of maintaining the channel. During the progress of the improvement the removal of many existing wrecks would be essential to success. These operations, not being under my charge, are not included in the estimate submitted, and the matter is not formally discussed in the body of my report.

Before closing, I cannot omit mentioning the great obligations I am under for the very material aid I have received in the consideration of this report from my able assistants, Capt. Charles J. Allen, Corps of Engineers, U. S. A.; Robert E. McMath, chief civil assistant; and Civil Assistants I. D. McKown, conducting the survey of the river from the mouth of the Illinois to the mouth of the Ohio River, and his assistant, Samuel H. Yonge; and D. M. Currie, Charles S. True, and S. E. McGregory, conducting the operations, respectively, at Devil's Island, Horsetail Bar, and Turkey Island, and Alton Slough, and the upper portion of Saint Louis Harbor. Every one of these gentlemen has contributed, from his intelligence, observation, and experience, to the results arrived at; and it is a matter of congratulation that all concur in the principles presented, and the plan of operations pursued and proposed.

I am also indebted to Mr. William Popp, civil assistant engineer and draughtsman, for the delineation of the maps submitted with the report.

The map accompanying this report is in four sheets—

1. Extending from the mouth of the Illinois to the mouth of the Missouri.
2. Extending from the mouth of the Missouri to Turkey Island.
3. Extending from Turkey Island to Cape Girardeau.
4. Extending from Cape Girardeau to the mouth of the Ohio.

All of which is respectfully submitted.

J. H. SIMPSON,
Col. of Eng., Brt. Brig. Gen., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

1876

2. *White River, above Jacksonport.*—The small balance remaining of the appropriation for this work has been expended during the last fiscal year in caring for the Government property belonging to the improvement and in completing a report upon a plan of permanent improvement for this portion of White River.

With regard to the improvement of Upper White River the officer in charge estimates the cost of giving a navigable depth of 2½ feet from Jacksonport to Batesville, 2 feet from Batesville to Sylamore, and 18 inches from Sylamore to the head of Buffalo Shoals, at $710,234.37, the improvement to consist of dikes for concentrating the water and for reducing the local slopes. Before the work is commenced additional surveys are needed. For this and for snag-boat work an estimate for the coming fiscal year is submitted by the officer in charge.

Amount available July 1, 1875	$7,771 26
Amount expended during fiscal year ending June 30, 1876	7,771 26
Amount appropriated by act approved August 14, 1876	10,000 00
Amount (estimated) required for completion of existing project	710,234 37
Amount that can be profitably expended in fiscal year ending June 30, 1878	57,700 00

(See Appendix L 2.)

3. *Improvement of White and Saint Francis Rivers.*—No appropriation has been made for work on these streams during the present season, but as work is much needed there the officer in charge submits an estimate for a snag-boat and expense of operating same.

For building one stern-wheel iron snag-boat	$60,000 00
For operating same 10 months, at $4,000 per month	40,000 00
	100,000 00

(See Appendix L 3.)

EXAMINATIONS AND SURVEYS FOR IMPROVEMENT.

To comply with provisions of the river and harbor act of March 3, 1875, Major Suter was charged with and has submitted a report upon the *survey of Missouri River at the point where it is cutting into the Kansas shore above Saint Joseph's, Missouri.* (See Appendix L 4.)

IMPROVEMENT OF MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS—IMPROVEMENT OF OSAGE RIVER.

Officer in charge, Col. J. H. Simpson, Corps of Engineers, having under his immediate orders Capt. C. J. Allen, Corps of Engineers.

1. *Improvement of the Mississippi River between the mouths of the Illinois and Ohio Rivers.*—The unexpended balance of the appropriation of $15,000, of June 23, 1874, and the appropriation of $15,000, of March 3, 1875, for application between the Illinois and Missouri, were applied to the construction of a low dam at Piasa Island, with the exception of $197.30 used in repairs of the dam opposite Alton, and a small balance yet available for continuing work.

The further sum of $15,000 is provided by the act of August 14, 1876, for expenditure between the Illinois and Missouri. With this sum and the small balance of the previous appropriation, it is proposed to continue the construction of the dam at Piasa Island, and apply $1,500 to the necessary repairs and extension of the abutments of the dam opposite Alton.

Work at Sawyer Bend, in Saint Louis Harbor, was confined to an expenditure of $1,466.68 for repairs. The limited appropriation for the present year does not justify the continuation of work at this locality.

The sum of $2,791.53 was applied to the partial restoration of the condition of Long Dike, near Venice, previous to its injury by ice in the spring of 1875. Further repairs are required to keep the dike at its proper height, which will involve an estimated expenditure of $2,500. No work is proposed here the present year.

Owing to changes at and near Arsenal Island, the condition of the channel at Horsetail Bar was very unfavorable during great part of the season of 1875. An additional dike was located and considerable progress made in its construction. The dikes contemplated in the original project at this locality have effected all that could reasonably be expected of them in their incomplete state. The foundations being well advanced, it is now necessary to raise the dikes to such height as may be found necessary to control the channel at the mean stage of water. Their influence hitherto being limited to low stages, the difficulties at the mean stage have not been removed. It is contemplated to raise the dikes and extend them to their full length as soon as possible.

The dams at Fort Chartres, Towhead, and Turkey Island are well advanced and can be completed the present year. The channel has continued good in the section of river which was expected to be improved by these works.

The channel at Liberty Island having changed, during the high water of 1875, from the east to the west side of the island, it became unadvisable to close the Missouri chute as contemplated, and it was thought best to devote the means allotted to the locality to the protection of the west bank opposite and above the head of the island. This protection was necessary to prevent the river getting into such condition as to render a return to the old channel impossible. Present appearances indicate that the west chute will remain the channel, rendering the extension of the protection necessary, which it is proposed to do the present year.

The works at Devil's Island were continued during the year. The channel was crooked, but the depth was maintained. The dike in the Missouri chute settled during the high water of 1875, and required a large amount of material to restore it to its former height. The construction of the dams in the Illinois chutes was succesfully continued.

New works have been authorized by Congress in the river and harbor act, approved August 14, 1876, at Cahokia Chute and Arsenal Island. The closure of Cahokia Chute cannot be undertaken with the means provided, which will all be required for the revetment of the island. The island is wasting rapidly, and causing great injury to the navigation of the river below. The closure of the chute is a work which must be done in one season, and therefore the appropriation of $75,000 is necessary in a single sum, if Congress sees fit to make a specific appropriation for the purpose.

Provision is made in the recent act requiring $5,000 to be expended between islands No. 14 and No. 15, near the town of Kaskaskia. This sum is insufficient to accomplish useful results, as it would be unsafe to place so small an amount of protection at the threatened point, lest it be flanked and detached from the shore, to be an obstruction to the channel.

A similar provision requires $30,000 to be expended for the protection of the banks between the foot of Dickey's Island and the mouth of the Ohio River, which will be done the present year. The commencement of this work will involve its continuation to the full extent estimated in the special report dated February 5, 1876. (See H. R. Ex. Doc. 126, 44th Congress, 1st session. See also Appendix M 4, of this report.)

The officer in charge submits an estimate of $500,000 for the fiscal year ending June 30, 1878. This estimate is a reduction of preceding estimates of 50 per cent., and is submitted as the least amount that can be profitably expended. The necessary expenses of administration and repairs of existing works consume a considerable percentage of small appropriations, and, as the item of repairs must necessarily increase, the percentage so consumed must increase unless the appropriation be liberal enough to allow a vigorous prosecution of the works to completion.

The appropriation of the above sum is recommended.

Amount available July 1, 1875	$208,337 42
Amount expended during fiscal year ending June 30, 1876	192,612 74
Amount available July 1, 1876, including $2,133.38 due on contracts	15,724 68
Amount appropriated by act approved August 14, 1876	229,600 00
Amount (estimated) required for completion of existing project	6,279,600 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	500,000 00

(See Appendix M 1.)

2. *Improvement of Osage River, Missouri.*—The funds for this work were exhausted at the beginning of the fiscal year, and as Congress made no provision for further work, the property which had been used in the improvement and surveys was disposed of at public auction, and the proceeds, less expenses of sale, turned into the Treasury. (See Appendix M 2.)

3. *Survey of the Mississippi River, near Kaskaskia, Ill.*—Under an apprehension that a serious erosion might, at an early day, occur at the junction of the Kaskaskia with the Mississippi, at the request of the Representative in Congress from that district, Colonel Simpson was instructed to cause a special examination to be made of the locality, with the view of suggesting a remedy, if necessary. (For his report, see Appendix M 3.)

IMPROVEMENT OF THE UPPER MISSISSIPPI RIVER BELOW SAINT PAUL—IMPROVEMENT OF LES MOINES AND ROCK ISLAND RAPIDS OF THE MISSISSIPPI RIVER—IMPROVEMENT OF ILLINOIS RIVER.

Officer in charge, Col. J. N. Macomb, Corps of Engineers, having under his immediate orders Capt. Amos Stickney, Corps of Engineers.

1. *Improvement of Upper Mississippi River.*—The United States steamer Montana was employed, as heretofore, in rendering temporary aid to navigation in opening channels through bars by the use of Long's scraper, pulling snags, and removing overhanging trees, and also in building low dams and jetties, to contract the river and permanently improve the channel.

On account of the great age of the Montana, and the consequent increasing expense from year to year to repair and fit her for service, the officer in charge recommends the purchase of a new iron hull for her machinery, which is in excellent condition; also of new steel boilers. His estimate of the cost of new hull, boilers, and transfer of machinery, and for current expenses during the year is $91,500.

Amount available July 1, 1875	$23,539 49
Amount expended during fiscal year ending June 30, 1876	21,929 63
Amount available July 1, 1876	1,609 86
Amount appropriated by act approved August 14, 1876	30,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	91,500 00

(See Appendix N 1.)

Dike D:			
280 piles	$1,512 00		
4,800 cords of brush	12,000 00		
4,700 cubic yards of stone	8,400 00		
	21,912 00		
Engineering and superintendence, 10 per cent	2,188 00		
	24,100 00	Cost of dike D..	24,100 00
Dike E:			
200 piles	1,080 00		
3,300 cords of brush	8,250 00		
3,800 cubic yards of stone	6,650 00		
	15,980 00		
Engineering and superintendence, 10 per cent	1,620 00		
	17,600 00	Cost of dike E..	17,600 00
Total cost			69,400 00

Very respectfully,

MAX BOEHMER,
Assistant Engineer.

Maj. CHARLES R. SUTER,
Corps of Engineers, U. S. A.

APPENDIX M.

ANNUAL REPORT OF COLONEL J. H. SIMPSON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1876.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., August 26, 1876.

GENERAL: I have the honor to submit herewith my annual report for the fiscal year ending June 30, 1876.

Very respectfully, your obedient servant,

J. H. SIMPSON,
Colonel of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

M 1.

IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS.

BETWEEN THE ILLINOIS AND MISSOURI RIVERS.

The appropriation bill approved March 3, 1875, required that $15,000 should be expended within the above limits. As the dam at Alton Slough had been completed under previous appropriations, it was decided to commence the construction of a dam at Piasa Island. Bids were received for this work June 29, 1875, of which an abstract accompanied my report for the fiscal year ending June 30, 1875. The high

stage of water prevented the commencement of operations until the latter part of August. Construction was commenced August 26, and continued until November 30. The dam is located about 600 yards below the head of Piasa Island, and extends from the island to the Missouri shore, a distance of 3,070 feet.

The shore connections were secured by a longitudinal wall of riprap, and revetment of the slope extending 100 feet below the line of the dam. The foundation of the dam is completed, except for a space of 400 feet near the middle of the stream, which was occupied by a high bar. At the close of the season the apron had been raised to the height of low water, and nearly the whole volume of water was compelled to pass through the Illinois chute. The water over the bar near the head of the island was reported to have deepened from 4½ to 8 feet. It will be necessary to complete the prism of the dam the coming season, and to fill the interval left open last year. It will also be necessary to revet the head of the island, which is now exposed at low stages to a rapid current. Estimated cost to complete the dam, $25,000. The expenditures on account of this dam were:

518 piles	$2,158 62
677.4 cords brush	1,016 10
158.51 cubic yards spalls	31 70
7,928.27 cubic yards riprap	9,276 07
Engineering and contingencies, 29.9 per cent	3,728 24
	16,210 73

The river and harbor bill approved August 14, 1876, requires the further expenditure of $15,000 between the Illinois and Missouri, of which the greater portion, $13,500, it is proposed to expend in the construction of this dam, leaving an estimated balance of $11,500 to be provided by future appropriations.

ALTON DAM.

This work has remained in the condition reported last year, except that the eddies below the dam have cut into the bank below the revetment and are enlarging. The west abutment was partially repaired last fall with 162.31 cubic yards of riprap, at a cost of $197.30. Repairs and extension of the abutments will be necessary the ensuing year, at an estimated cost of $1,500. The repairs required are to be made from the funds provided in the river and harbor bill of the present year; and it is not anticipated that further funds will be needed for this work.

The cost of this work to date has been:

6,730 cubic yards excavation	$1,682 50
584 piles	1,223 80
1,543.82 cords brush	3,401 80
12,108.89 cubic yards riprap	17,126 15
5,657 cubic yards spalls	5,657 00
Labor	739 45
Engineering and contingencies, 5.2 per cent	1,557 75
	31,368 45

Original estimate, $40,000.
The length of the dam is 996 feet.

SAWYER BEND.

Work at this locality has been limited to repairs, using—

1,040.31 cubic yards riprap, at cost of	$1,269 18
Engineering and contingencies	197 50
	1,466 68

The appropriation of March 3, 1875, did not warrant the extension of this work last year, and it was thought that delay would not be a disadvantage, as the bend above was being cut out to a more favorable shape. The cutting has progressed now as far as is desirable, and it is hoped that provision will be made for the continuation of the work at an early date.

To carry out the recommendation of the board contained in their report of April 13, 1872, at this point requires the extension of the protection 4,365 feet. The original estimate was $142,211.62, of which $91,981.12 have been expended, leaving $50,230.50 remaining to be appropriated, which will be sufficient to complete the work, if made available at once. The small amount appropriated by the bill for the present year will not warrant the continuation of work at this locality. The balance of estimate, $50,230.50, is therefore to be provided by future appropriations.

The account with this work is:

31,975 cubic yards excavation	$5,755 50
Dredging	11,195 91
630 piles	3,439 37
4,942.12 cords brush	14,113 40
30,780.80 cubic yards riprap	40,746 00
2,622.01 cubic yards revetment	4,850 72
1,210.37 cubic yards spalls and macadam	1,391 48
Labor	1,521 50
Engineering and contingencies, 10.8 per cent	8,967 24
	91,981 12

LONG DIKE NEAR VENICE.

This work was partially restored to its condition previous to the injury by ice in the spring of 1875. Complete repairs were prevented by the high stage of water in July and August of 1875. There has been expended during the fiscal year for—

2,125.85 cubic yards riprap	$2,593 53
Engineering and contingencies	198 00
	2,791 53

Repairs will probably be required to keep this dike at its proper height during the coming year to the amount of $2,500.

The account with this work is:

517 piles	$3,364 55
1,944.63 cords brush	4,893 06
18,618.71 cubic yards riprap	24,668 45
Engineering and contingencies, 10.4 per cent	3,415 79
	36,341 85

for raising 1,469 feet of old dike, extending 600 feet, and construction of T-head. In the original project the extension of two other dikes was joined with this, in an estimate of $197,323.90. These dikes it is not advisable to extend at present, nor until the rights of riparian proprietors are examined and adjusted, to avoid claims for heavy damages. No work can be done here the present year.

HORSETAIL BAR.

The favorable results reported last year at this locality were not continued during the season of low water, 1875. The crossing which had given trouble in previous years was reported last year to have deepened

about 2 feet, which deepening it was hoped might be permanent, an expectation which was but partially realized. During the high water of the summer of 1875, very extensive erosions were made from the head of Arsenal Island and from the Illinois bank in Cahokia Bend; the eroded material from these sources passed the narrow section of river in front of South Saint Louis, (Carondelet,) and was dropped in the upper part of the wide expanse called Horsetail. This deposit caused an obstruction which, though called by the old name, is located 1½ miles above the bar whose removal had been the object in previous years. At the locality of the new obstruction the depth had previously been at least 6 feet at all stages. This deposit filled the whole bed of the river to the height of 8 or 10 feet above the normal low-water plane. The dikes which had been built in the vicinity were raised to the height of 8 feet above low water; therefore, when this new deposit was made the dikes were below its general level, and could exert no influence upon the currents until the bar was washed down to the level of the dikes. When this occurred the channel first cut out a crooked course around the head of dike No. 1, which was difficult to follow; later the channel deserted this position, and, after opening temporarily at several points in the width of the river, at the end of the season crossed to the Illinois Shore and followed it down to dike No. 3; then, turned aside by the dike, it crossed back to the Missouri Shore. After it had established itself in this location, there was little trouble on account of depth, but the channel was crooked and difficult. The increased depth in the final location proves that the channel had previously been shoal only because it was continually shifting its position in the recently-deposited bar, whose uncompacted material yielded more readily to the current at the side than at the bottom. These movements of the new bar involved the removal of vast quantities of material, which was again deposited at the lower end of the reach, and occasioned some trouble on the lower crossing. The condition of the navigation showed the necessity of the immediate construction of dike No. 2, which was commenced in October, upon the site indicated in the project submitted April 28, 1873. The late date of its commencement did not permit it being advanced far enough to exert any appreciable influence last fall; but it is hoped that it will exert a beneficial effect the present year, although it is 500 feet short of its contemplated length of 1,800 feet.

In order that the dikes should be able to exert an influence upon the channel at the higher stages, and prevent the recurrence of the conditions of last year, it will be necessary to raise them at the shore ends to the height of a mean stage, and make the profile a slope from the bank to the outer end of the dikes. This change in the profile was indicated by the experience of previous years; that of last year proves that the immediate execution of the change is necessary. A survey of the locality was made at low water in December, 1875, which showed that there had been an accumulation of sand on the Illinois side held by the dikes, which corresponded closely with the line of improvement. This sand-bar was nearly of the height of the dikes 3, 4, and 5, and extended from No. 3 to the head of Carroll's Island. Nos. 4 and 5 being nearly buried, must be credited with having accomplished all that could be expected of them in their incomplete state.

The high water in July, 1875, afforded a severe test of the experiment at dike No. 5, mentioned in the report of last year, as the water flowed over the revetted sand embankment to the depth of 5 feet without injuring the dike; but, on the contrary, the dike was strengthened by deposits. At the junction of the earth embankment with the riprap

part of the dike, near the edge of the dry bar, the dike was undermined, and settled about 15 feet as a maximum, the breach being about 210 feet wide; this breach was filled, and the earth embankment extended 200 feet inshore to a connection with the levee. The embankment now slopes from the height of the levee to 8 feet above low water in a distance of 1,300 feet. It was contemplated to extend this dike last year to its full length, but the site became inaccessible in September, and the extension was not begun. A part of dike No. 3 settled during the high water, and required repairs; the settlement was confined to the 400 feet nearest the Illinois shore, where, when the dike was commenced, the water was 20 feet or more in depth. The bottom here was light sand, deposited probably in a deep channel at some recent period. The settlement being in deep water, a large amount of material was required to close the breach. Dikes 1 and 4 were not injured, and required no repairs.

During the spring and summer of 1876 the high-water deposits have been similar to those of 1875. At the date of this report the only practicable channel crosses dike No. 1 about midway of its length, the outer end of the dike being buried in a reef. It is probable that the first channel cut out will be around the end of the dike; if so, the history of last year will be repeated. The completion of dike No. 2 and raising of No. 1 is an immediate necessity; it is therefore proposed to apply $50,000 of the present appropriation to work at this locality.

The expenditures on account of the several dikes at Horsetail Bar during the fiscal year ending June 30, 1876, were:

For dike No. 2:		
254 piles	$1,087 86	
1,405.14 cords brush	2,107 70	
9,296.83 cubic yards riprap	10,924 19	
114 hours' labor	22 80	
Engineering and contingencies	1,421 48	
		$15,564 03
For dike No. 3:		
5,218.81 cubic yards riprap	$6,174 04	
Engineering and contingencies	513 41	
		6,687 45
For dike No. 5:		
3,900.58 cubic yards riprap	4,601 01	
182.32 cubic yards embankment	18 23	
Labor	38 30	
Engineering and contingencies	580 00	
		5,237 54
		27,489 02

Which, deducted from estimate given in transportation-route report, January 23, 1875, of $100,000, leaves $72,510.98 to be appropriated.

The total cost of the works at this locality has been:

Dike No. 1, 1,171 feet long, with T-head, 200′ × 80′:		
510 piles	$2,953 33	
1,755.25 cords brush	5,183 00	
12,232.49 cubic yards riprap	17,208 11	
91.29 cubic yards spalls	127 81	
Engineering and contingencies, 5.5 per cent	1,401 58	
		$26,873 83
Dike No. 2, 1,300 feet long:		
254 piles	1,087 86	
1,405.14 cords brush	2,107 70	
9,296.83 cubic yards riprap	10,924 19	
114 hours' labor	22 80	
Engineering and contingencies, 10.05 per cent	1,421 48	
		15,564 03

Dike No. 3, 1,375 feet long:

249 piles	1,263 43	
371.8 cords brush	1,366 48	
27,999.56 cubic yards riprap	40,896 00	
Labor	329 62	
Engineering and contingencies, 8.3 per cent	3,651 27	
		47 506 80

Dike No. 4, 2,070 feet long:

342 piles	1,483 84	
792.26 cords brush	2,804 60	
20,876.18 cubic yards riprap	31,071 07	
Labor	75 00	
Engineering and contingencies, 9.7 per cent	3,213 66	
		38,648 17

Dike No. 5, 2,400 feet long:

242 piles	1,063 65	
743.8 cords brush	2,087 88	
9,610.98 cubic yards riprap	13,618 73	
8,100.32 cubic yards embankment	1,977 24	
Engineering and contingencies, 8.8 per cent	1,651 55	
		20,399 05
Total		148,991 88
Unappropriated balance of estimate		72,510 98
Total estimated cost of present project		221,502 86

DAM AT FORT CHARTRES ISLAND.

The work at this point was commenced in the fall of 1874. During the last fiscal year the body of the dam was filled in to the height of 8 feet above low water, except for 300 feet at the west end. It is estimated that 6,500 cubic yards of riprap will complete the dam, at a cost of $9,750. The dam is 1,592 feet in length, and has received material during the fiscal year as follows:

28 piles for moorings	$100 94
10,648.6 cubic yards riprap	15,879 88
1,218.8 cubic yards spalls	1,267 55
Engineering and contingencies	1,061 86
	18,310 23

The total cost to date has been:

504 piles	1,957 34
1,057 cords brush	2,081 60
18,625.2 cubic yards riprap	28,588 24
1,218.8 cubic yards spalls	1,267 55
Engineering and contingencies, 8.8 per cent	2,993 13
	36,887 86

It is proposed to complete the dam the present year.
The original estimate for work in this vicinity was $75,000.

TURKEY ISLAND DAM.

This dam was commenced in the spring of 1875, and was continued until the chute became inaccessible early in the fall. The chute has been rapidly filled by the river during the last two years. The dam is 1,834 feet in length, and at the time work was suspended stopped the water from passing at the stage of 7 feet above low water. It having been built upon shallow foundations, considerable settlement is liable to take place. Without settlement, it is estimated that 7,000 cubic yards of riprap will complete the dam, at cost of $11,000.

Material has been used during the year as follows:

13 piles, for moorings	$67 78
278.3 cubic yards spalls	289 43
6,355.9 cubic yards riprap	9,560 65
Engineering and contingencies	681 24
	10,599 10

The total cost of dam is:

41 mooring-piles	$206,98
10,935.8 cubic yards riprap	18,262 45
278.3 cubic yards spalls	289 43
Engineering and contingencies, 14.9 per cent	2,806 60
	21,565 46

Owing to the late date of the passage of the river and harbor bill, it will not be practicable to complete the dam this year, as it is inaccessible at low stages; but it is necessary to continue the work so far as possible.

Original estimate for works in this vicinity was $100,000.

LIBERTY ISLAND.

This locality has, for several years, been a great obstacle to navigation. The act approved March 3, 1875, authorized the application of $15,000 to the locality. It was contemplated to close the Missouri chute by a dam, and one was located and the construction of the west abutment begun; but after the high water of July and August passed it was found that the Illinois chute was unnavigable, and that the tendency of the channel was to desert it altogether. It was therefore decided to suspend work on the dam and devote the season to a revetment of the Missouri bank opposite and above the head of the island to preserve a direction which would be favorable if the channel should take the Missouri chute, and prevent the cutting progressing so far as to render a return to the Illinois chute impossible. On engineering grounds alone the Missouri chute is fully as desirable, when cleaned of snags and wrecks; but the small town of Rockwood is situated on the Illinois chute, and its interests should not be sacrificed. It is therefore deemed advisable to wait another year before deciding which chute should be closed.

In the protection of the bank there was expended:

12 piles, for moorings	$13 27
9,596.6 cubic yards riprap	14,298 93
720.2 cubic yards spalls	749 01
Engineering and contingencies, 9.3 per cent	1,406 47
	16,197 68

For the abutment of the dam:

19.7 cubic yards spalls	$20 49
3,029.9 cubic yards riprap	4,616 21
Engineering and contingencies, 8.3 per cent	387 21
	5,053 91

The excess over $15,000 was taken from the portion of the appropriation not specifically located by Congress.

It is very necessary that the revetment of the bank should be raised throughout the portion commenced last year, which covers a front of 3,774 feet, and the protection should be extended 2,709 feet to a connection with the dam abutment now in place, at an estimated cost of $26,610.

The original estimate for the locality was $100,000.

DEVIL'S ISLAND.

The high water of July and August, 1875, caused considerable change in the condition of dike No. 1 after the annual report was written. The foundation of the dike had been completed in the fall of 1874, and the dike raised to the height of 6 feet above low-water mark; but the foundation rested on a sand bar whose surface for a great part of the length of the dike was above low-water mark. During the spring and summer the extensive dry bar above and attached to the opposite bank moved down stream so far that when the water fell the current drew across the dike; as a consequence, the foundation settled. The greatest change was near the shore, where the dike settled from 6 feet above to 30 feet below low water. Near the middle the change was slight, and the outer end was sunk irregularly, varying from 6 to 15 feet. The strongest current being along shore, the bank above and below the dike was considerably eroded, and it was deemed necessary to revet the bank for a distance of 1,000 feet above the dike; of this distance 625 feet was protected during the season. In this protection a single mattress of brush was sunk, 495 feet in length by 50 feet in width, containing 566.14 cords brush. The success of this experiment justifies the expectation of a material cheapening of the cost of protective works.

The channel last year passed close around the end of the dike, and as the bar above was likely to continue to move down stream, it was not deemed advisable to repair the outer end of the dike. The breach near shore was filled nearly to the final profile.

The foundation of dam No. 1, in the chute between Devil's and Picayune Islands, was completed, the east-shore connection secured, and considerable progress made in filling the body of the dam. When inspected in June last it was apparently undisturbed, and the chute appeared to be filling.

At dam No. 2, in the chute between Picayune Island and the main Illinois shore, no work was done except to place material previously delivered.

The expenditures during the year were:

Dike No. 1:		
566.14 cords brush	$1,9[illegible]6 53	
3,034.51 cubic yards spalls	3,130 24	
17,1[illegible]0.99 cubic yards riprap	25,951 32	
Excavation and labor	456 56	
Engineering and contingencies	1,63[illegible] 10	
		$33,162 75
Dam No. 1:		
Excavation and labor	$54[illegible] 36	
652.[illegible]5 cords brush	2,245 39	
2,544.28 cubic yards spalls	2,854 41	
9,75[illegible].72 cubic yards riprap	15,2[illegible] 57	
167 piles	620 [illegible]0	
Engineering and contingencies	[illegible]29 10	
		22,3[illegible]6 63
Dam No. 2:		
Labor	$3[illegible] 50	
		3[illegible] 50
		55,5[illegible]7 [illegible]8

The total cost of these works is:

Dike No. 1, 1,000 feet in length and 625 feet shore-protection:		
45[illegible] piles	$1,374 00	
2,043 cords brush	6,[illegible]02 44	
21,601.43 cubic yards riprap	35,556 10	
3,034.51 cubic yards spalls	3,130 24	
Excavation and labor	456 56	
Engineering and contingencies, 6.5 per cent	3,[illegible]60 52	
		$50,399 68

Dam No. 1, length 1,750 feet:		
528 piles	$1,703 80	
2,291.86 cords brush	7,910 95	
15,443.79 cubic yards riprap	26,852 80	
2,544.78 cubic yards spalls	2,854 41	
Excavation and labor	548 36	
Engineering and contingencies 5.1 per cent	3,213 74	
		43,084 06
Dam No. 2, length 350 feet:		
104 piles	$315 06	
682.98 cords brush	1,627 73	
2,982.34 cubic yards riprap	6,211 24	
Excavation	38 50	
Engineering and contingencies 15.7 per cent	1,286 65	
		9,479 18
		102,963 10

The total estimate for works in this locality was $250,000, leaving for future operations $147,036.90, of which $47,036.90 will be required to complete the works already begun; and of this sum it is proposed to spend $30,000 the present year.

CLOSING CAHOKIA CHUTE.

Although the closing of this chute is partially provided for in the new river and harbor bill, approved August 14, by a distinct clause and a specific sum, the work itself is part of the general scheme for the improvement of the Mississippi River, and bears a very important relation to the improvement of the navigation. When the special report was made, under date of January 23, 1875, (see Report of Chief of Engineers for 1875, page 497, part 1,) there was no apparent reason for the opinion that the immediate closure of the chute was necessary in the interests of navigation. After the date of that report a rapid cutting away of the head of the island commenced, which has progressed rapidly since, and furnished material for deposits which greatly obstructed navigation at Horsetail Bar. This erosion still continues. The head of the island has been cut away so much that the head is now nearly one-half mile farther down stream than at the date of the map accompanying the report. A large area of the highest part of the island has disappeared. It is now of the greatest importance that this erosion should be stopped and the chute closed. The appropriation just made will all be required to revet the island to secure it from further erosion and the consequent destruction of the site for a dam. The dam itself must await further appropriations. The original estimate did not include the cost of protecting the island, the necessity for which was not then apparent. The estimate of funds required for the dam remains, $75,000, all of which should be granted in one appropriation, as the work is not divisible.

KASKASKIA BEND.

This locality was made the subject of a special report, dated April 28, 1876, in which an estimate was submitted amounting to $42,000. The late bill requires that $5,000 should be expended at this locality. It is very difficult to put in language all the reasons that conspire to render the application of small sums to the control of a mighty stream like the Mississippi wasteful. I will endeavor to make this case illustrate the general principle. The extent of front that it is necessary to protect is 6,000 feet: the estimated cost is $7 per foot, which would suffice if all the work was provided for at once. Undertaken with the sum of $5,000,

the cost would need to be taken at $10 per foot on account of limited amount of work; therefore 500 feet would be the extent of protection. Five hundred feet of the length of one of the sweeping bends of the Mississippi is comparatively but a patch, and practically exerts no controlling influence above or below; the protected front may be held, but the bank retreats both above and below, and the projection becomes a disturbing element, which, by creating eddies, intensifies the destruction in its vicinity, when a longer firm front would by virtue of its length restrain the eddies and deliver the current smoothly at the lower end. The application of so small a sum cannot therefore be made where the need is greatest, but must be located at the very head of the caving bank, entirely above the point where the destruction is active, and cannot extend far enough to afford any relief to the interests endangered, and whose influence has obtained the appropriation. Since the special report was made the caving has continued, and at the apex of the bend the caving amounts to 250 yards. From the direction of this recent caving the danger of a junction with the Kaskaskia is less imminent than when the report was written, the apex being now below the point of nearest approach of the two rivers. If this work is commenced under the present appropriation, its continuation next year becomes a necessity. If a special sum is to be set apart for its continuation it should not be less than $25,000 to accomplish useful results.

PROTECTION ABOVE CAIRO.

A special report upon this locality constitutes House of Representatives Executive Document 126, 44th Congress, first session. The estimate there given for the protection of the Illinois shore is $172,500, of which $30,000 is provided for the present year, which it is proposed to apply at the point of greatest danger to the navigation. For the continuation of this work, at least $30,000 should be provided the coming year.

I would respectfully call attention to the fact that the estimates for the improvement of the Mississippi River are divided into two distinct parts: first, for deepening the channel, $3,159,200; second, for protective works, $4,000,000. If the purpose of Congress is to improve the navigation of the river and realize useful results at an early date, the distinction made in the estimates should be observed. The deepening of the channel precedes protection in order of execution and importance to navigation. Protective works have closer relation to individual and local interests, and are therefore more likely to be pressed upon the attention of Congress, in efforts to secure specific sums for specified localities; and it may not be out of place to suggest that private jobs are sometimes brought forward under the specious mask of public improvements. If Congress is disposed to accede to requests for the execution of these protective works in advance of their logical and natural order in the scheme of improvement, it should be with the understanding that all sums taken and made applicable to the protection of banks is so much deducted from the appropriation for the improvement of the navigation of the Mississippi River.

SURVEYS.

No extended surveys were made during the year. Special examinations were made at Piasa Island, Horsetail and Twin Hollow Bars, Liberty Island, and a resurvey from Dickey's Island to the mouth of the Ohio. The cost of these surveys was $4,799.90.

The total expenditure for surveys since the organization of this office in 1870 has been:

Survey from Alton to mouth of Meramec River	$7,7[illegible]4 21
Survey at Cabaret Island	3,595 07
Board of engineers, convened by S. O. No. 20, H. Q. C. of E., February 7, 1872	736 91
Survey from mouth of Missouri River to mouth of Ohio River	22,024 91
Triangulation from mouth of Missouri River to mouth of Ohio River	21,39[illegible] 20
Special surveys, local	1[illegible],303 30
Total	73,[illegible]42 63

Of which $48,008.77 was specially appropriated; the balance, $25,833.86, was borne by the general appropriation.

Of the above total $27,518.21 was expended by my predecessor, Lieut. Col. W. F. Raynolds.

EQUIPMENT.

As has been stated in previous reports, the interests of the work required that the Government should own a portion at least of the equipment needed to carry on the work.

The equipment now on hand is sufficient for the needs of the work, if continued upon the moderate scale of the past. A condensed statement of the property-account is given for information. It includes in the *Dr.* column the charter and operating expenses of steamers and barges; the *Cr.* column shows the value of the services rendered, and the *balance* column the amount with which the several classes of property are now charged upon the books of the office.

Class of property.	Dr.	Cr.	Balances.
Office furniture	$[illegible]90 55	5[illegible]0 60	$500 55
Instruments and survey material	4,791 [illegible]0	3,941 [illegible]0	[illegible]50 00
Five pile-drivers	15,144 91	5,073 52	10,071 39
Eighteen barges and two quarter-boats	70,1[illegible]4 27	29,[illegible]44 81	40,379 46
Tools	6,136 52	4,221 52	1,915 00
Quarters for workmen, shops, &c	4,744 51	2,556 72	2,177 79
Two tow-boats and one steam-tug and expenses	130,177 98	73,775 14	56,402 [illegible]4
Small boats	5[illegible]2 [illegible]2	3[illegible]6 00	1[illegible]6 [illegible]2
General expense of property	13,556 65	61 16	13,495 49
Material and quarry privileges	202,567 65	200,605 95	1,961 70
Total	44[illegible],747 66	320,[illegible]66 62	127,[illegible]1 04

Construction account.

Name of work.	Amount expended.	Amount required to complete.	Total.
Piasa Island dam	$16,210 73	$25,000 00	$41,210 73
Alton dam	31,368 45	[illegible],631 55	40,000 00
Sawyer Bend protection	91,981 12	50,230 50	142,211 62
Long dike	36,341 85	3,658 15	40,000 00
Horsetail Bar, dike No. 1	20,[illegible]73 63		
Horsetail Bar, dike No. 2	15,564 03		
Horsetail Bar, dike No. 3	47,506 80	72,510 98	221,502 [illegible]6
Horsetail Bar, dike No. 4	3[illegible],648 17		
Horsetail Bar, dike No. 5	20,399 05		
Fort Chartres dam	36,[illegible]87 86	9,750 00	46,637 86
Turkey Island dam	21,565 46	11,000 00	32,565 46
Liberty Island dam	5,053 91	*	5,053 91
Liberty Island protection	16,497 68	26,610 00	43,107 68
Devil's Island, dike No. 1	50,399 86		
Devil's Island, dam No. 1	43,084 06	47,036 90	150,000 00
Devil's Island, dam No. 2	9,479 18		
Total	507,[illegible]62 04	254,428 08	762,290 12

* Will not be continued.

DR. *Engineer Office, United States Army, in account with United States.* CR.

To allotments from appropriations for examinations and surveys on northern and northwestern lakes and rivers, and Atlantic and Pacific coasts, &c., made prior to 1872	$16,623 07	By expenses of office	$31,036 86
To allotment from appropriation for examinations and surveys and contingencies of rivers and harbors, approved June 10, 1872	21,355 70	By general engineering	19,945 52
To appropriation for improvement of Mississippi River from Illinois to Missouri, approved June 10, 1872	25,000 00	By surveys	73,842 63
To appropriation for improvement of Mississippi River from Missouri to Meramec, approved June 10, 1872	100,000 00	By construction	507,862 04
To appropriation for improvement of Mississippi River from Missouri to Ohio, approved March 3, 1873	200,000 00	By balances on account of property	127,891 04
To appropriation for improvement of Mississippi River from Ohio to Illinois, approved June 23, 1874	200,000 00	By cash on hand July 1, 1876	17,724 68
To allotment from appropriation for surveys and estimates for improvements on transportation-routes to the seaboard, approved June 23, 1874	10,000 00		
To appropriation for improvement of Mississippi River from Illinois to Ohio, approved March 3, 1875	200,000 00		
To unpaid percentage on annulled contracts	900 17		
To percentage due on existing contracts	2,133 38		
To amount due on non p yment roll	250 45		
	776,292 77		776,292 77

The original estimates for the improvement of the Mississippi River between the Illinois and Ohio Rivers began with an estimate contained in the report of a Board of Engineers dated April 13, 1872, (Report of Chief of Engineers for 1872, page 366,) which was—

For erection of dike at Alton Harbor	$10,000 00
For protection of 2 miles of Sawyer Bend	142,211 62
For extension and raising of dikes in Northern Harbor of Saint Louis	197,323 90
For survey between Alton and the mouth of the Ohio River	30,000 00

Following this report, Congress appropriated, by act approved June 10, 1872—

For improvement of Mississippi River between the Illinois and Missouri	$25,000 00
For improvement of Mississippi River between the Missouri and Meramec	100,000 00

and ordered a survey of the river from the Missouri to the Ohio, for which there was allowed $22,584.79.

The above amount applicable to the section from the Illinois to the Missouri was applied to construction of the Alton Dam, and that applicable from the Missouri to the Meramec was applied to the protection of Sawyer Bend and extension of Long Dike.

The survey from the Missouri to the Ohio was made, and a preliminary report submitted under date of December 18, 1872. In that report estimates were given for—

Deepening the channel of the Mississippi River from the Missouri to the Ohio	$893,895 00
For securing the river in its present channel	2,102,149 00
Total	2,996,044 00

Following this report, an appropriation was made by act approved March 3, 1873—

For the improvement of the Mississippi River between the Missouri and Ohio	$200,000 00
And by act approved June 23, 1874	200,000 00

By the act of June 23, 1874, a survey was ordered of the Mississippi transportation route, and there was allotted for the survey from the Illinois to the Ohio $10,000.

The report of this survey was made January 20, 1875, and is published in Report of Chief of Engineers for 1875, part 2, page 471.

In this report an estimate was given for—

Improving the channel between the mouths of the Illinois and Ohio Rivers.	$3,159,200
For revetments between the mouths of the Missouri and Ohio Rivers.....	4,000,000
Total.....	7,159,200

This last estimate covered the whole ground and includes the items of the preceding estimates which remained unprovided for at its date.

To arrive at the total estimated cost of improving the Mississippi River from the Illinois to the Ohio it is necessary to add to—

The estimate of 1875.....	$7,159,200
The sum of appropriations previously made.....	525,000
Making an aggregate of.....	7,684,200
Of which up to July 1, 1876, there has been appropriated.....	725,000
Leaving for further appropriations.....	6,959,200

A glance at these figures will show that at the rate of $200,000 per year, as for the last three years, thirty-five years will pass before the appropriations equal the estimates; the annual grant has been less than 3 per cent. of the total estimate, and 3 per cent. upon the original cost would be a very low figure for the maintenance of the completed work. It will be readily understood that with such small appropriations the completion of the improvement is postponed to an indefinite but distant future, for as progress is made the expense of maintaining the works will consume an increasing proportion of the annual appropriation, and eventually take it all. The estimates given were made with an allowance of but 10 per cent. for contingencies added to the cost of material. Examination of the construction accounts will show that the contingent items of cost vary from 5.2 per cent. to 29.9 per cent.; or taking a mean they are equal to $\frac{44,182.88}{463,679.16} = 0.09\frac{53}{100}$ per cent. The cost of administration is $\frac{31,036.86}{709,585.71} = 0.04\frac{37}{100}$; and the cost of general engineering is $\frac{19,945.52}{709,585.71} = 0.02\frac{81}{100}$. The two last items represent the cost of an engineer office and organization, the expense of which would not be perceptibly increased if the amount of business were much larger. The minimum ratio, 5.2 per cent, for contingencies of construction could easily be made the mean rate, if means were provided for a rapid execution of each individual work to completion. A large item in construction account is for transportation of material; the cost of transportation per unit depends in great measure on the quantity, as every business man well knows. Taking the aggregate of all the items into consideration, there can be no question but that $500,000 appropriated in one year will do as much work as $600,000 divided into three annual sums of $200,000 each. Last, year in estimating the amount required, $1,000,000 was given as the amount that could be profitably expended during the fiscal year ending June 30, 1877. The estimate for the year ending June 30, 1878, is for the least amount that can be profitably expended, $500,000.

Money statement.

Balance in Treasury of United States July 1, 1875:		
On account of appropriation for improvement of Mississippi River, from the Illinois to the Ohio, approved March 3, 1875:		
For application between the Illinois and Ohio	$136,000 00	
For application between the Illinois and Missouri	15,000 00	
Amount in hands of officer and subject to his check, July 1, 1875:		
On account of appropriation for improvement of Mississippi River, from the Missouri to the Meramec, approved June 10, 1872	132 55	
On account of appropriation for improvement of Mississippi River, from the Ohio to the Illinois, approved June 23, 1874:		
For application between Ohio and Illinois	3,082 54	
For application between Missouri and Illinois	4,739 83	
On account of allotment from appropriation approved June 23, 1874, for surveys and estimates for the improvements recommended, by the Senate Committee on Transportation Routes to the Seaboard, &c., to be expended in the survey of that portion of the Mississippi route lying between the mouth of the Illinois River and the mouth of the Ohio River	392 50	
On account of appropriation for improvement of Mississippi River, from the Illinois to the Ohio, approved March 3, 1875:		
For application between Illinois and Ohio	49,000 00	
		$202,337 42
Amount expended during fiscal year ending June 30, 1876:		
On account of appropriation for improvement of Mississippi River, from the Missouri to the Meramec, approved June 10, 1872	132 55	
On account of appropriation for improvement of Mississippi River, from the Ohio to the Illinois, approved June 23, 1874:		
Between Ohio and Illinois	3,082 54	
Between Missouri and Illinois	4,739 83	
On account of allotment from appropriation approved June 23, 1874, for surveys and estimates for the improvements recommended by the Senate Committee on Transportation Routes to the Seaboard, &c., to be expended in the survey of that portion of the Mississippi route lying between the mouth of the Illinois River and the mouth of the Ohio River	392 50	
On account of appropriation for improvement of Mississippi River, from Illinois to the Ohio, approved March 3, 1875:		
Between Illinois and Ohio	172,958 08	
Between Illinois and Missouri	11,317 24	
		192,612 74
Amount available July 1, 1876, including $2,133.32 due on contracts:		
On account of appropriation for improvement of Mississippi River, from the Illinois to the Ohio, approved March 3, 1875:		
For application between Illinois and Ohio	12,041 92	
For application between Illinois and Missouri	3,682 76	
Amount appropriated by act approved August 14, 1876, for improvement of Mississippi River, between the Illinois and Ohio:		
For application between Illinois and Ohio Rivers	150,000 00	
For application between Illinois and Missouri Rivers	15,000 00	
For application between Islands No. 14 and No. 15, near the town of Kaskaskia, Ill	5,000 00	
For application between the foot of Dickey Island and the mouth of the Ohio River	30,000 00	
Amount appropriated by act approved August 14, 1876, for improvement of the channel of the Mississippi River, opposite the city of Saint Louis, Mo., by the construction of a low dam across the channel east of Arsenal Island, known as Cahokia Chute, and in the revetment of said island	29,600 00	
		245,324 68
Amount (estimated) required for completion of existing project		6,729,000 00
Amount required for fiscal year ending June 30, 1878		500,000 00

The collection-district in which the work is located is New Orleans.

Amount of revenue collected at the port of Saint Louis for the fiscal year ending June 30, 1876, was $1,592,407.09.

Abstract of contracts for improvement of Mississippi River between the Illinois and Ohio Rivers, let under the appropriation approved March 3, 1875, agreeably to proposals opened June 29, 1875.

Name of contractor.	Date of contract.	Section.	Character and price of material, &c.														
			Pile timber.	Piles driven 10 feet—Government furnishing machinery.	Piles driven 10 feet—contractor furnishing machinery.	Piles driven in excess of 10 feet—Government furnishing machinery.	Piles driven in excess of 10 feet—contractor furnishing machinery.	Brush.	Stone for riprap from Government quarry.	Stone for riprap from private quarry.	Spalls.	Gravel.	Sand, loam, or clay excavation.	Transportation of material unit 1 yard, 100 feet.	Common labor of men.	Common labor of teams.
			Per foot.	Per pile.		Per foot.		Per cord.	Per cubic yard.					Per yd., 100 ft.	Per hour.	
Henry Doering	July 15, 1875	First section	$0 03	$2 50	$3 00	$0 01	$0 02	$1 50	....	$1 17	$0 20	$0 50	$0 10	$0 01	$0 22½	$0 25
Do	July 15, 1875	Second section	03	2 50	3 00	01	02	1 50	$1 15	1 22	30	50	10	01	20	30
George Williams	July 15, 1875	Third section	05½	1 00	1 00	03	03	1 60	75	80	30	20	......	......	......	......
Do	July 15, 1875	Fourth section	06	1 00	1 00	03	03	1 75	85	90	35	20	......	......	......	......