

220 REPORT OF THE CHIEF OF ENGINEERS, U. S. ARMY.

IMPROVEMENT OF MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS—IMPROVING HARBOR AND MISSISSIPPI RIVER AT ALTON—ICE HARBOR AT SAINT LOUIS, MISSOURI—IMPROVING MISSISSIPPI RIVER AT OR NEAR CAPE GIRARDEAU, MISSOURI, AND MINTON POINT, ILLINOIS—IMPROVEMENT OF OSAGE RIVER IN KANSAS AND MISSOURI.

Officer in charge, Capt. O. H. Ernst, Corps of Engineers.

1. *Mississippi River between the Illinois and Ohio Rivers.—Piasa Island.*—A project for the improvement of the river in this vicinity was prepared; but before the works could be begun, the funds available were withdrawn in consequence of the proviso attached to the appropriation of March 3, 1881, and reappropriated for the purposes of the improvement of the river at Alton.

No other work was done between the Illinois and Missouri Rivers during the year, and none is contemplated under the general appropriation during the coming year.

Cahokia Chute.—The present project for the improvement of this locality was adopted in 1876, the object being to stop the inroads of the river into the Illinois bank, and the consequent deterioration of the navigation. This object was successfully accomplished last year; the amount expended up to June 30, 1880, being \$116,088.00. To finally complete the improvement of the navigation in this vicinity it will be necessary to shut off all the water from Cahokia Chute.

No work was done here during the year, and none is contemplated during the coming year.

Horsetail Bar.—The present project for the improvement of this locality was adopted in 1873 and modified in 1879, the object being to afford a channel not less than 8 feet deep. The natural channel was often not more than 4 feet deep at the shoalest part. The amount expended during the year was \$116,078.53. The total amount expended to June 30, 1881, is \$511,529.44, and has resulted in securing a channel in which it is expected that the depth will not be less than 7 feet during the coming year. A balance of \$33,921.47 remains available from the appropriation of June 14, 1880, with which it is expected to practically complete the work, though it will be the object of care for an uncertain number of years.

Twin Hollow and Widow Beard's.—A project for the improvement of these two adjoining localities has been adopted, the object being to afford a channel not less than 8 feet deep. The natural channel has sometimes been not more than 4 feet deep in the shoalest part. The works have not yet been begun. An allotment of \$115,000 has been made from the appropriation of March 3, 1881.

Kaskaskia Bend.—The present project for the protection of this bank was adopted in 1876 and modified in 1880, the object being to stop the caving in a bend 23,000 feet long. The amount expended during the year was \$12,326.34. The total amount expended to June 30, 1881, is \$66,465.62, which was applied to the direct revetment of about 6,000 feet of bank and to work designed to change the direction of attack of the river. The work was this spring almost wholly, if not wholly, destroyed by the action of ice and flood. The results are therefore practically nothing. The officer in charge in his annual report sets forth at length the reason why this work should not be resumed in the interest of navigation; and he points out some objections to resuming it for the protection of local interests. Should it be deemed proper to resume it, a large appropriation, not less than \$100,000, should be made available

before the work is begun. A radical change in the course of the river is required, the final cost of which, if caused by artificial means, cannot now be estimated. Rapid changes are going on in the vicinity, and it would seem proper to allow these to continue until the stream has worked itself into better shape than the present one. No appropriation is recommended. The sum of \$5,697.25 allotted to this work by the river and harbor act of June 14, 1880, remains unexpended. As this sum alone cannot be used here to any useful purpose, it is recommended that provision be made in the next river and harbor bill for its application to the general improvement.

Protection between Dickey Island and the mouth of the Ohio.—The present project for the protection of this bank was adopted in 1876, the object being to stop the caving in a bend 11,500 feet long. The amount expended during the year was \$6,517.23. The total amount expended to June 30, 1881, is \$119,868.66, and has resulted in the protection of 10,700 feet of bank previously unprotected and in the repair and strengthening of the works previously built by the Cairo Land Company, covering a length of 3,500 feet more, making in all 14,200 feet of bank. To entirely complete this part of the protection a small amount of work will be required this year.

Estimate.—The appropriation of \$1,000,000 asked for is to be applied to completing the works now progressing and to continuing those to be begun this year at Twin Hollow, Widow Beard's Island, and between the mouth of the Meramec and Rush Towhead, and to beginning new works below the latter place.

The programme is to make the improvement continuous, working down stream from Saint Louis, by reclaiming land and building up new banks, thus reducing the width of the river to the uniform width of about 2,500 feet. It is proposed by this means to secure a minimum depth of 8 feet. The depth is now liable to become as little as 4 feet in some places and less than 8 feet in every place where the width is greater than 2,500 feet. Caving banks are to be protected. From the changeable nature of the stream, it is not practicable to give in advance the exact localities where work will be required. The appropriation of this sum is recommended.

July 1, 1880, amount available.....	\$283,338 57	
Amount appropriated by act approved March 3, 1881.....	600,000 00	
		<hr/> \$883,338 57
July 1, 1881, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1880.....	231,395 81	
Amount reappropriated by act March 3, 1881.....	33,354 70	
July 1, 1881, outstanding liabilities.....	1,778 71	
		<hr/> 266,529 22
July 1, 1881, amount available.....	616,809 35	
		<hr/>
Amount (estimated) required for completion of existing project*.....	5,539,420 32	
Amount that can be profitably expended in fiscal year ending June 30, 1883	1,000,000 00	

(See Appendix R 1.)

2. *Improving harbor and Mississippi River at Alton.*—This work, for which provision was made in the river and harbor act of March 3, 1881, has not yet been begun. The project adopted has for its object the removal of the shoal now existing in front of the Alton landing.

The officer in charge submits an estimate of \$86,675.30 as the amount

* NOTE.—Amount reappropriated by act of March 3, 1881, to be applied to harbor and Mississippi River at Alton and amounts expended at Kaskaskia Bend are added to estimate of last year.

APPENDIX R.

IMPROVEMENT OF MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS—IMPROVING HARBOR AND MISSISSIPPI RIVER AT ALTON—ICE-HARBOR AT SAINT LOUIS, MISSOURI—IMPROVING MISSISSIPPI RIVER AT OR NEAR CAPE GIRARDEAU, MISSOURI, AND MINTON POINT, ILLINOIS—IMPROVEMENT OF OSAGE RIVER IN KANSAS AND MISSOURI.

REPORT OF CAPTAIN O. H. ERNST, CORPS OF ENGINEERS, OFFICER IN CHARGE, FOR THE FISCAL YEAR ENDING JUNE 30, 1881, WITH OTHER DOCUMENTS RELATING TO THE WORKS.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., August 11, 1881.

GENERAL: I have the honor to transmit herewith my annual reports for the fiscal year ending June 30, 1881, upon the works under my charge.

Very respectfully, your obedient servant,

O. H. ERNST,
Captain of Engineers.

- Brig. Gen. H. G. WRIGHT,
Chief of Engineers, U. S. A.

R 1.

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

BETWEEN THE ILLINOIS AND MISSOURI RIVERS.

At the date of my last annual report the sum of \$33,825.85 was available for expenditure within these limits. A survey had been made of the river in the vicinity of Piasa Island with a view to preparing a plan for the improvement of that locality. The map was in course of preparation.

As soon as the map was completed it was made the subject of study and a project for the improvement was prepared, an outline of which is shown upon the adjoining sketch, Plate 1. It was forwarded to the department with my report of August 26, 1880. A Board of Engineers having been convened to report upon this project met in Saint Louis November 23, 1880.

The working season had already terminated on account of the unusually early advent of winter. Before the opening of the spring of 1881

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the funds available were withdrawn and reappropriated for another purpose by the following proviso in the river and harbor act of March 3, 1881, viz:

* * * And the sums of money heretofore appropriated for the improvement of the Mississippi between the Illinois and Missouri Rivers and unexpended are hereby reappropriated, and shall be applied to the improvement of the harbor and Mississippi River at Alton.

The sums referred to amount to \$33,354.70. They will be accounted for hereafter in a separate annual report (see report upon harbor and Mississippi River at Alton).

The gauges at Grafton and Alton were read daily. The records are hereto appended, that of the former marked A, and that of the latter marked B.

No other work was done within these limits during the year, and none is contemplated under the general appropriation for the coming year.

CAHOKIA CHUTE.

The dam constructed across this chute in 1878 and repaired in 1879 has settled about 3 feet, leaving its crest about 6 feet above the low-water of 1863; otherwise it remains in good condition. It has fully accomplished the first result expected of it, viz, stopping the erosion of the Illinois shore. The second and more important result—the improvement of navigation by deepening the water in the chute west of Arsenal Island—is now becoming evident. Heavy shoaling has taken place during the recent high-water in the upper part of Cahokia Chute, which will shut off nearly all the water from that chute at medium and low stages. This must necessarily be followed by a marked improvement in the navigation of the other chute.

The height of the deposit already much exceeds the height of the dam. The work of the latter may be regarded as nearly finished. The present navigable channel will become better as the new river bank at the head of Cahokia Chute becomes higher.

The complete reclamation of this ground will be necessary to finally complete the improvement of the navigation, and this will probably require some supplemental works in the future. But the process of building up the new bank is going on now in so satisfactory a manner that it is thought best to do nothing further at this locality until the favorable impulse given by the dam shall have finally expended itself.

HORSETAIL BAR.

Operations at this locality were continued throughout the year whenever the elements would permit it. A long winter and a flood in the spring impeded the work and prevented its completion. Plate 2 shows the location of the works as they have now been constructed. Under the influence of the hurdles on the Illinois side, aided by changes caused by the dam across Cahokia Chute, several miles above, the channel early last autumn was shifted to the desired location on the Missouri side, as shown.

This change rendered it possible to suspend the construction of hurdles on the Illinois side sooner than had been anticipated. The influence of these works in causing deposits was felt all the way to Carroll's Island, 2 miles below, but so long as the efforts of the river were directed towards retaining its channel through them, it was necessary to re-enforce them by adding to their number. These efforts having been to a

great degree withdrawn, the works upon this side were suspended at secondary hurdle No. 29. The construction of hurdles on the Missouri side was begun in the spring, and was executed at a high stage of the river, the disadvantage of working in deep water being more than compensated for by the richer supply of building material carried by the river at that season.

The total length of primary hurdles—the name given to the longitudinal hurdles located upon the line of the new bank—constructed during the year was 9,500 feet, of which the cost, including engineering and contingencies, was \$37,540.63, or \$3.95 per linear foot. The total length of secondary hurdles, the name given to transverse lines, was 22,000 feet, of which the cost, including engineering and contingencies, was \$78,537.90, or \$3.57 per linear foot.

Of these totals 1,900 feet of primary hurdle and 11,630 feet of secondary hurdle were constructed upon new ground. The balance were consumed in reconstructing and repairing the work of this and of the previous year. This adds \$8.53 per linear foot to the cost given last year of the dike built with floating curtains in prolongation of the training-wall, now called primary hurdle, making the total cost \$24.28 per running foot. At the beginning of the year 31,000 linear feet of secondary hurdles had been constructed. The additions give 42,630 feet among which the repairs are to be distributed.

The process of building up the new banks has continued in a satisfactory manner. There have been occasional drawbacks when, a breach being made in the hurdles, the water would concentrate in a small channel and scour out some of the new deposit. Damages of this kind are to be expected at this stage of the work, and have been anticipated from the beginning. They are necessarily attendant upon a system in which brute strength is largely replaced by vigilance.

The breaches have been promptly and easily repaired. The final results for the year have been a substantial gain at nearly all points. Enormous deposits have been secured over the entire area between secondary hurdle No. 29 and Carroll's Island, as well as within the areas inclosed by the hurdles. Those on the Missouri side have been quite uniform in thickness, the top presenting a regular surface. Those on the Illinois side have in some cases taken the shape of the long conical bars peculiar to the Mississippi, and differ largely both in the actual thickness of deposit and in the height to which they extend. The height attained in some cases exceeded all expectation. The crest of one bar—the highest—made its appearance at a 31-foot stage, the fill at that place having been 23 feet since last July. Greater fill has occurred elsewhere, but at lower levels. The top of this bar was higher than the old bank; it has since shrunk to about the same height. The largest fill in the two years was secured in the deep hole just below the old dike 3, where, in the spring of 1879, there was a depth of 70 feet at a 12-foot stage. Dry bar has appeared at this place this year at a 22-foot stage, showing a fill of 80 feet. At some places, on the other hand, the fill has been but a few inches, though, as a general rule, such places have been under the influence of the works for but short periods. Plates 2 and 3 show the position of the deposits as they would appear at a 15-foot stage at the end and at the beginning of the year. That is the stage above which it is believed that the willow will grow, and at which further reclamation may be left to nature. The appearance of the bars at a lower stage is shown upon the sketches accompanying the report of Mr. Currie, assistant engineer.

The total quantity of material deposited within the area to be re-

claimed since the introduction of this system two years ago is over 13,000,000 cubic yards. This volume taken from the water-way of the river must be replaced by the excavation of a nearly equal volume, unless the area of cross-section and velocity of the stream are largely altered; an occurrence which is not the least probable. The beneficial effect upon the channel may be expected with perfect confidence.

The change in the location of the channel was a great gain, but was at first attended by a decrease in the depth below what was found the year before. The material composing the bars on the Missouri side consisted largely of coarse gravel, many of the pebbles measuring 3 inches in diameter. The excavation of this material was comparatively slow. Three principal reefs were developed.

On the 20th of August the depth upon the upper the reef—the most prominent one—was but 6 feet 6 inches, the Saint Louis gauge reading 11 feet 6 inches. This reef was raked with a large harrow dragged by the steamer Anita, and in a few days a depth of 1 foot additional was made.

The river then rose and the reefs were not again noticeable by navigators until October. On the 22d of October, the gauge reading 10 feet 2 inches, the depth was 6 feet on both the second and third reefs, the depth on the upper reef being about a foot greater. The steamer not being available, the harrow could not be used, and there being a less depth at some other points between Saint Louis and Cairo, the river was left to do its own excavation. This it did slowly but effectually. On the 3d of December, navigation being suspended on account of ice, with the gauge reading 4 feet, the depth on the three reefs was 4 feet 5 inches and 4 feet 6 inches, respectively.

On the 15th of December, with the gauge reading 5 feet 6 inches, the least channel depth on any reef was 7 feet; that is, there had been a total vertical cut since August of 6 feet 6 inches.

It being the habit of the river in wide places such as this to drop a portion of its sediment in its channel at high stages, it was expected that much of this excavation would have to be renewed during the coming year when the water falls. The channel depth has therefore been watched with considerable interest during the prolonged high-water of this spring.

The highest stage reached by the river was 33.65 feet, May 6. On the 9th of May, the stage having fallen to 29.9 feet, the least channel depth was 31 feet, showing a fill of less than 5 inches since December. On the 4th of June, the gauge reading 21 feet 4 inches, the depth was 21 feet, showing a fill of 1 foot 10 inches since December.

On the 9th of July, the gauge reading 21 feet 6 inches, the depth was 17 feet, showing a fill of 6 feet since December. Under the circumstances—the river remaining above a 20-foot stage for over four months, during two of which it was above 25 feet, and for two weeks above 30 feet—this fill is remarkably small.

The material thus deposited is light alluvion, the removal of which is very different from that of the heavy gravel excavated last autumn. It is expected that its removal will be accomplished so rapidly that the reefs will not again appear as obstructions, at least until a stage lower than that of last autumn is reached. The amount of this channel filling at high-water should diminish as the height of the new banks is increased.

The results of the year's work have been such as to increase the confidence felt in the efficiency of the system of construction here adopted.

The break-up of the ice this spring was the most violent of which there is any record. The flood which followed nearly equaled that of 1826 in height, and has never been exceeded more than four times, as far as known. A combination of two such occurrences in one year is a rarity that need not be expected more than once in half a century.

The total destruction of such portions of the works as had not completed their work of reclamation at the time of the break-up might have been anticipated. Instead of this, only a portion of the primary hurdle was carried away, and the injuries to the secondary hurdles were not excessive. Equal damage would have been inflicted upon any ordinary dike, however massively constructed. Although more extensive repairs than usual have been rendered necessary, largely increasing the cost, the works upon the whole have passed through the ordeal in a very satisfactory manner.

The experience of the year has led, however, to some modifications in the details of construction, which, though increasing the original cost, are thought to be in the interest of economy.

The floating curtains, supported at one side by buoys, and anchored on the other side to the bottom, of which several forms were illustrated in my last annual report, were originally introduced for application in very deep water, where piles could not be used to advantage. They served their purpose well, causing the depth to decrease so that piles could afterwards be used, and they may again be resorted to where great depths are to be contended with. But their employment cannot be advantageously extended to shoal-water, for the reason that it is not practicable to devise a thoroughly efficient buoy which shall at the same time be cheap. For all depths less than 35 feet the most efficient support for the brush obstacle is the pile, which acts in the double capacity of anchor and buoy.

For depths of 10 or 12 feet, sometimes increased to 15 feet, the brush is wattled directly upon the piles. In greater depths light hurdle-work mattresses are launched from floating ways, and secured in a vertical position against the piles.

The reasons for this difference are that in considerable depths the work of sinking the brush course by course is tedious and expensive, and the structure, when finished, has great buoyancy, tending to lift the piles.

The mattress launched against the piles is deprived of its buoyancy by the load of stone at one side which is used in sinking it. All piles are now braced, except in very shoal-water, 6 feet or less depth, the braces being introduced at intervals of 20 feet. The primary hurdle is provided with a footing of brush.

But little additional information relating to the plantation and growth of willows has been obtained. Cuttings of the larger diameters have more vitality than those of the smaller. A cutting should not be less than 1 inch in diameter. Nothing new concerning the lowest level at which the willow will grow has been procured, for the reason that the cuttings planted at the lower stages were either washed away or were covered with mud, and were lost. That level is believed to be not far from 15 feet above the low-water of 1863. A vigorous plant is not killed by being covered with mud and water for many weeks.

The works at Horsetail were under the supervision of Mr. D. M. Currie, assistant engineer. His report, to which attention is invited for details, is appended, marked E.

The expenditures were \$116,078.53.

TWIN HOLLOW AND WIDOW BEARD'S.

A detailed hydrographic survey of the river, from the foot of Carroll's Island to the mouth of the Meramec, was made in October by my assistant, Mr. P. O. F. West. A plan for the improvement of this portion of the river, which includes the two notorious localities known as "Twin Hollow" and "Widow Beard's," was submitted with my report of January 28, 1881. An outline of it is shown upon the adjoining sketch, Plate 4. It has not been practicable to begin these works for want of the necessary plant. The large additions now being made to the latter, and the near completion of the works at Horsetail, will render it possible to push these new works with vigor during the present season.

PROTECTION OF BANK NEAR KASKASKIA.

Operations were resumed at this locality as soon as the water had fallen to a suitable stage, in the latter part of September. The work of former years was found breached in two places and more or less damaged in several others. The water, entering through the breaches in the form of eddies, had excavated curious bays of elliptical form. The diameter of one of these bays at the mouth was 180 feet, and the horizontal distance to which it had entered the bank was 135 feet. Orders were given to cut these bays off from the river by a line of fixed hurdles, built upon the line of the old bank, with a view to stopping the action of the water-auger and to causing deposits instead of excavation. Orders were given also to repair and strengthen the old work, after which it was to be extended down stream, using brush throughout instead of stone as before, for the high-water portion, and to begin the construction of a series of hurdle-dikes designed to change the direction of attack of the river.

Only a portion of this programme could be carried out. The hurdles crossing the mouth of one of the bays was completed and immediately gave beneficial results. Piles were driven for a similar construction at the other bay, but before the wattling could be completed a suspension of the work was made necessary by the advent of severely cold weather. To strengthen the old work two mattresses, measuring respectively 750 and 265 feet in length by about 80 feet in width, were sunk at the foot of the slope, outside the former protection. They overlapped each other by about 10 feet, thus giving a continuous protection to about 1,005 feet of bank.

To change the direction of attack of the river, a hurdle-dike was begun at the foot of Sainte Genevieve Island and built out to a total length of 1,140 feet, the outer 380 feet, however, not being completed. It acted in the manner expected of it, causing heavy deposits. On the 17th of November 4 inches of snow fell, and heavy ice formed in the river, putting a sudden stop to the work. This proved to be the permanent advent of winter, and operations were not resumed.

The works at Kaskaskia Bend were under the local supervision of Mr. Max E. Schmidt, assistant engineer. For a detailed description of them attention is invited to his report, extracts from which are appended, marked F.

During the severe winter which followed these operations, ice was formed in the river, varying from 1 to 2 feet in thickness. On the 10th of February the river rose 8 feet at Saint Louis, the most extraordinary rise in a single day on record. The enormous forces developed by this rise were disastrous to the work. Great fields of heavy ice thrown

against the outer portion of the hurdle-dike promptly destroyed that portion. The ice soon gorged in the channel south of Sainte Genevieve Island, about 4 miles above Kaskaskia Bend, forcing a large body of water down the north chute (see adjoining map, Plate 5). This chute was rapidly enlarged, and the dike was attacked in the rear. The ice gorging between the dike and the main Illinois shore, a deep channel was cut through the root of the dike between the latter and Sainte Genevieve Island. The water rapidly rose above the dike, and the latter, what is left of it, has been submerged ever since. It is probably almost wholly, if not wholly, destroyed.

The direct protection suffered severely also. Standing as it does nearly at right angles to the direction by which the stream approaches from above, it was exposed to such assaults as immense fields of ice 2 feet thick moving with a velocity of 7 or 8 miles an hour can give. A field of this character striking the shore seemed checked for a moment, but it was presently observed to be moving slowly up the bank, carrying a slice of the bank-protection and all with it. Many layers were piled up over each other upon top of the bank 30 feet above low-water. In this manner the part of the bank which was above the water surface was stripped of its protection. As this enables the river to cut in behind the mattresses at the foot of the slope, it is probable that most of this work also is destroyed. The prolonged high-water of this spring has rendered it impracticable to ascertain with accuracy what the condition of it is.

After the ice had done its work of destruction, the river rose steadily, with but few and slight oscillations, until in the latter part of April it went over its banks, and there was a flood.

The overflow, concentrating in a slight depression in the strip of land which separated the Kaskaskia River from the Mississippi, formed a considerable stream, which poured into the former river with a fall of about 6 feet. This overfall soon cut a deep hole in the soft, alluvial soil which constitutes the river's bed, and then began the process of cutting back towards the Mississippi, with which a junction was soon formed. This cut was opposite the lower end of the work, upon which further damage was inflicted. A deep excavation approaching the revetment from the rear totally destroyed it throughout the width of the cut. The cut is now about 500 feet wide and 30 feet deep when the Mississippi is at a 22-foot stage. There has been no enlargement as yet of the Kaskaskia River below the cut.

The total result of the ice and the flood, so far as it can now be ascertained, is that it will be necessary to begin the work again from the beginning.

In this state of affairs it is a pertinent question whether the work should be abandoned or should be begun anew. The accompanying map, Plate 5, shows the position of Kaskaskia Bend with reference to the Kaskaskia River, and to the Mississippi for some miles above and below. The position of the channel is represented by the broken black line. It shows where the efforts of the main stream are directed. Passing out of Sainte Genevieve Bend, the channel crosses over to the Illinois side and enters Kaskaskia Bend in a direction nearly at right angles to the Illinois shore. The Illinois bank thus constitutes an obstacle directly in the path of the river. The results are the same as those given by any other great obstacle, viz, a sharp change of direction, a heaping up of the waters, an increase of slope and velocity, with their attendant difficulties for ascending navigation. It is certainly not in the interest of navigation to make the present location of the channel permanent.

Curvature much more gentle than that here existing is required to give safe and easy navigation.

The necessity of this becomes still more apparent when the stability of the works is considered. The protection of the bank causes increased scour at its foot. It is evident that in the case of a curve which is unnaturally sharp, like this one, the additional scour must be unusually great. While this adds materially to the difficulty and cost of the work, it is believed to be practicable to hold the bank so long as water alone is to be resisted. But the movements of ice introduce new complications. For security against these, easy curvature is a necessity.

This cannot be obtained without a radical change in the location of the channel somewhere between Little Rock and Chester. To push the stream out of Kaskaskia Bend, filling up that bend and cutting off the point opposite, retaining the present position of the channel above and below, would accomplish this result with less injury to the inhabitants of the country than any other plan that occurs to me.

This would be an operation of great magnitude, and should be undertaken only with that understanding. Whether it could be finally accomplished at all is doubtful. The dike built last autumn at the foot of Sainte Genevieve Island was the first step towards that end, and there can be no assurance that similar works in the future will not meet a similar fate. In any event, the operation would be a long and costly one. To move bodily one of the largest rivers in the world from one place to another is no small undertaking. Navigation must necessarily be interfered with more or less during the execution of the work. Its cost cannot be estimated any more than that of a battle, which it would in many respects resemble. It would be several hundred thousand dollars at least.

The recent enlargement of the chute north of Sainte Genevieve Island—the map is constructed from a survey of last year and does not show the enlargement—and the cut into the Kaskaskia River suggest two ways by which the river may accomplish the necessary straightening in the next few years, if left to itself.

Other ways may be developed by the stream itself in a short time, for changes are rapid where the shape is so unnatural as in the present case.

In carrying out the programme of working down stream from Saint Louis in the general improvement of the river adopted for reasons given further on under the head of appropriation of March 3, 1881, it may be several years before this locality is reached. In the mean time the river will probably have worked itself into a better shape, but, whether that happens or not, the approach to any works which may be constructed here cannot be assured until after the improvement of the river above.

If the funds to be employed in this work are to come from the general appropriation for improving the navigation, as heretofore, there can be no question that the interests of navigation require that the work should now be abandoned.

It is true that the work was originally undertaken for the protection of land, and not for the improvement of navigation, and that this interest will suffer by its abandonment.

Experience has shown that the land which is immediately threatened cannot be protected without turning the river entirely away from it, or bringing it to it in a direction totally different from the one by which it now approaches. In either case other land must be destroyed, and in the latter case Sainte Genevieve would be deprived of navigable water. The river must be straightened. In whatever way that be accomplished, some one must suffer, fertile land must be destroyed, and

riparian owners, possibly town sites, must be deprived of navigable water. These injuries, if inflicted by the government, would be a just cause of complaint; if inflicted by the river without artificial aid, they are the act of a power from whose judgment there is no appeal. There are therefore objections also to undertaking at this time a rectification of the river for the purpose of protecting the local interests now endangered. Should it be thought proper, however, to do this, it is desirable that the money be provided separately from the general appropriation for improving the navigation, and that a large sum, not less than \$100,000, be made available before the work is begun. It is to be remarked that this is the value, at \$50 per acre, of 2,000 acres of land.

The expenditures were \$12,326.34, leaving a balance of \$5,697.25, which by the act of June 14, 1880, is required to be expended in this vicinity. As the employment of this sum alone would be simply to throw it away, it is desirable that it should be made available by new legislation for expenditure in the general improvement of the river.

DICKEY'S ISLAND TO MOUTH OF OHIO.

A few breaks in the revetment of the bank in rear of Cairo were found to have occurred, and the short working season of last autumn was devoted to their repair.

This work was under the general direction of Mr. Max E. Schmidt, assistant engineer, and under the immediate charge of Mr. W. S. Mitchell, assistant engineer. The report of Mr. Mitchell to Mr. Schmidt is appended, marked G, to which attention is invited for details.

Alternating floods from the Ohio and Mississippi rivers have prevented the prosecution of the work this spring. The planting of willows upon the upper portion of the slope remains to be done.

The expenditures were \$6,517.23.

METHOD OF CARRYING ON THE WORK.

All work during the year has been done by hired labor and purchase of material in open market (except piles), and with satisfactory results. It is proposed to continue the system during the coming year, for the reason that the character of the work will not admit of the contract system without injury to the interests of the United States.

The reasons for this were fully set forth in my last annual report. (See Annual Report of Chief of Engineers for 1880, pages 1374, 1375.) These reasons still exist.

EQUIPMENT.

It had become evident before the close of the working season last autumn that a readjustment of the plant would be required to provide for the necessities of the works under the new system of construction. A considerable number of additional barges and pile-drivers would be required. Additional quarter-boats also were needed. It was thought best not to make any large additions until a new appropriation should be assured. The additions were at that time limited to one steam pile-driver, two quarter-boats, and three model barges. Advertisements for proposals for constructing the barges were inserted in the official advertising newspapers of Saint Louis, Cincinnati, Louisville, Ky., and Quincy, Ill., but only one proposal was received. This proposal being considered unduly high, it was rejected, and the barges were built by hired labor and purchase of material in open market. The pile-driver was constructed in the same manner.

The appropriation of March 3, 1881, providing for a large expansion of the work, corresponding additions to the plant have been necessary. For the expenditure of \$600,000 per annum, it was estimated that forty-five barges and twenty pile-drivers would be required. Of these, eighteen barges and six pile-drivers were on hand.

The most serviceable and convenient kind of barge, and the most economical in towing, is the model barge; but its high price has rendered it desirable to resort for the present to some other means of transportation. Twenty-seven second-hand coal barges or barge flats were procured from the Ohio River. These are now being fitted with capstans and rough decks, and otherwise repaired.

They are expected to last two or three years, at the end of which time they can be replaced by similar vessels or by model barges, as may be thought best.

To avoid the delay incidental to building by contract, the construction of fourteen new steam pile-drivers was begun in March by hired labor.

Progress upon them has been much impeded by the failure of lumber merchants to deliver material. At the end of the year five of them were completed and good progress was making upon the others. A detailed drawing of one of these machines was forwarded to the department with my letter of April 25, 1881.

With a view to keeping down to the lowest limit expenditures upon new plant, no additions have been made to the quarter-boats. Portable buildings, as kitchens, laborers' quarters, and offices, are in course of construction. These can be set up on shore and moved whenever it becomes necessary. They are less expensive than floating quarters, and, while not so convenient, can be utilized at the more extensive works, while the quarter-boats now on hand are employed at the places where the force is engaged for shorter periods. The principal objection to buildings on shore is the possible difficulty of procuring permission from the owners of land to put them up. This difficulty may vanish in practice, in view of the fact that they can be removed at a moment's notice.

Four buildings, each providing an office and quarters for an assistant engineer; four buildings, each providing kitchen, store-rooms, and mess-room for seventy-two laborers, and two buildings, each providing sleeping-quarters for seventy-two men, have been constructed.

The expenditures upon this plant were \$75,446.04.

As this extensive equipment cannot properly be charged to the cost of the work in any one year, a special record is kept, in which it is treated as so much unexpended appropriation.

Each work is charged for the use and repairs of such equipment as may be employed upon it. The amount proper to be charged is obtained from the first cost and average life of the vessel. Small repairs are charged to the work at the time when they are made. Extensive repairs, which increase the value of the vessel, are added to the balance remaining of the first cost, and treated like that. In this way an accurate statement of the actual cost of each work, including all contingencies, is procured.

It is in this way that the costs given in this report are ascertained. The present valuation of the property remaining to be distributed in the future is given in the last column of the following table, in which are given, also, its valuation at the beginning of the year, the sums which have been expended upon it, and its estimated deterioration during the year.

Class of property.	Balance, July 1, 1880.	Dr.	Cr.	Balance, June 30, 1881.
Steamer A. A. Humphreys.....	\$20,055 64	\$1,440 08	\$3,487 65	\$18,014 17
Steamer Anita.....	6,267 08	000 85	1,000 88	4,861 07
Launch Hornet.....	153 21	170 00	217 50	105 71
Tug Mignon.....	4,212 72	100 81	241 31	4,077 72
Barges.....	20,600 24	65,741 03	13,000 10	71,320 17
Pile drivers.....	2,370 72	36,612 03	4,700 30	33,170 65
Quarters, shops, &c.....	11,017 83	9,810 43	5,383 20	15,445 05
Skills, flats, &c.....	601 24	1,870 74	700 00	1,769 48
Tools and appliances.....	2,720 01	3,261 81	1,600 00	4,411 82
Office furniture.....	224 05	283 65	65 75	441 05
Surveying instruments, &c.....	1,050 70	108 75	60 50	1,114 05
Totals.....	78,120 33	100,001 37	31,605 05	165,025 04

SURVEYS.

The general topographical survey, which at the beginning of the year had been carried down as far as Kaskaskia Bend, was resumed in the latter part of July. It was learned a few days after the party had taken the field that the Mississippi River Commission were about to run a line of precise levels over the same ground. Levelling operations were at once suspended and the work was limited to tracing the shore lines and topography of the banks. These levels terminate at the mouth of the river Aux Vases. The topography having been extended to the foot of Cousin Will's Island, it was there suspended in the latter part of August until the completion of more pressing work, which required the services of the assistants and the plant. It was resumed in the latter part of October, and was extended by the 20th of November to Allen's Landing, where it was stopped for the season by severe cold weather. A pressure of other work has prevented its continuation this spring, but it is expected that it will be resumed at an early day.

The length of river surveyed was 21 miles. The work was executed with the plane-table upon a scale of $\frac{1}{100,000}$, using the old triangulation as a ground work. It was under the direction of Mr. P. O. F. West, assistant engineer.

Besides the special survey from Carroll's Island to the mouth of the Meramec, already alluded to, there has been undertaken this spring, under the appropriation of March 3, 1881, with a view to preparing plans of improvement and estimates of cost, a detailed hydrographic survey from the Meramec to White Sand Depot, omitting a stretch of 4 miles near Brickey's Mill.

Two parties have been employed under the respective direction at first of Mr. P. O. F. West and Mr. W. S. Mitchell, assistant engineers.

Mr. West having tendered his resignation, his party was placed in charge of Mr. J. O. Holman, assistant engineer. The field work is completed to Rush Towhead, 19 miles from the Meramec, where it has been suspended, as it is believed to be far enough in advance of the improvement to provide for present necessities. It is desirable in preparing plans to have the maps as recent as practicable. The survey will be resumed whenever the advance of the improvement renders it necessary.

The hydrographic maps made for the purpose of preparing plans of improvement have been constructed with the plane table, the scale being $\frac{1}{100,000}$. A hydrographic survey with this instrument being something of a novelty, Mr. West has, at my request, prepared a description of the method as devised by him, which is appended, marked II. The method has proved to be well adapted to the conditions of our work, in which

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the sheets of water are long, comparatively narrow, and tolerably straight. It is rapid, accurate, and economical, its cost being less than 75 per cent. of a transit survey executed to the same degree detailed.

The expenditures were for general topographical survey, 21 miles, \$1,906.62, and for detailed hydrographic surveys, 25½ miles, \$5,005.18.

The gauge at Gray's Point was read daily throughout the year.

A copy of the record is appended, marked O.

NAVIGABLE DEPTH BETWEEN SAINT LOUIS AND CAIRO.

The changeable character of the bars and shoals in this portion of the Mississippi River often making the navigation good at some place where in the previous year it was bad, and *vice versa*, render it desirable that a record should be kept of the depths found at different seasons at localities where obstructions are most often found.

Without a record of this kind the engineer often has tradition alone to guide him in deciding whether any given portion of the river shall be the subject of improvement or not. It will often happen that his hydrographic survey will show a good channel at a place where the year before it was very bad, and where the year after it may without improvement be the same.

It is evidently impracticable, on account of the cost, to provide special observers who shall watch the appearance and disappearance of every bar over a long stretch of river.

The Association of Saint Louis and New Orleans pilots have furnished me the means of compiling a record which will answer the purpose reasonably well, and will, I think, constitute a valuable contribution to the history of this portion of the river. Whenever a member of this association has passed over the river between Saint Louis and Cairo he immediately makes a written report to the association, noting any change in the location of the channel and the depths found upon the bars. These reports, after serving their purpose with the association, have been transferred to me.

The tabular statement appended, and marked D, gives the depths thus reported for nearly every day from the 1st of August to the close of navigation in November. The depths were measured with the ordinary sounding lead of the boat, except where they were less than 6', when a rod was usually employed, giving a more accurate measurement.

At high stages the boats frequently did not follow the deepest water, the reports were much less frequent, and the measurements themselves were much less accurate. The data procured in this way, at such times, would be misleading rather than instructive. The statement, therefore, does not include the reports made during the spring months.

The record, as it stands, gives a fair picture of the condition of the river during the low-water season, as it appeared to those engaged in navigating it. In many cases a less depth is reported by one person than was found by another on the same day, the difference being due to the difficulty of following out the deepest channel in a wide expanse of water. Strict accuracy cannot be claimed for any one measurement, but if several days be taken together, the gauge record also being considered, a close approximation to the depth existing throughout the season upon every bar will be found.

The river did not reach a very low stage this year, and the navigation upon the whole was better than it has sometimes been in former years. The least depth reported was that in the crossing from Wahoo to Cape Girardeau, which was 5'. The phenomenon of a falling river, attended

by a maintained or increased depth upon the bars, is illustrated in a number of cases.

Some well known localities do not appear in the list, because the navigation there has been good this year, and no soundings were taken.

An effort was made to procure similar reports for the portion of the river above Saint Louis, but it was not successful.

STANDARD LOW-WATER.

The lowest water recorded at Saint Louis is the low-water of 1863. That level constitutes the zero of the gauge at this place, and it is usual in speaking of low-water, without other qualification, to refer to the lowest water, or the zero of the gauge. The term low-water when applied to a plane of reference from which are to be measured the channel depths to be procured or maintained by the works of improvement, has never been defined.

Such a level must be determined by considerations different from those by which the zero of a gauge is fixed. The latter may be anywhere, it being convenient to place it so low that the reading shall always have the plus sign. Low-water of 1863 seems a very proper level for that purpose. But to take that as the level below which a depth of 8' is to be procured is to require more of the works than is necessary.

The season of lowest water always occurs in the winter, when the sources of supply in the North are closed by frost. At this season the river is subjected to ice gorges, which, while putting a stop to navigation, dam back the water and cause the gauges to give indications which are entirely abnormal. The low-water of 1863 occurred on the 21st of December, and there is every indication, in the record before and after, that it was occasioned by an ice gorge. For the purposes of navigation it is a matter of indifference how little a depth there may be in the channel when the river is frozen over. The level from which it will be proper to measure depths should be the lowest one to which the river is likely to fall during the navigable season. This can only be determined by a comparison of the gauge record with the dates upon which navigation has been suspended on account of ice for a considerable number of years.

The gauge record kept at Saint Louis up to October 16, 1871, gives simply an approximation to the different stages of the river. I am informed by Mr. Jacob Leopold, who kept the record, that there was no gauge.

The level of the water surface was ascertained by leveling down from the city directrix whenever the city surveyor happened to be on the spot, the stages for the days between such occasions being computed from the estimated rise or fall of the river since the previous leveling. While it is probable that the low-water of 1863 received special attention as being an extraordinary occurrence, it is evident that as a general rule the stages given in that record are not to be relied upon for the purpose of the present investigation. In October, 1871, a regular gauge was established by the Signal Service, and was read for the first time on the 16th of that month, and in 1873 the present permanent gauge was established by Major Merrill. A reliable gauge record exists, then, for only about 10 years. This is perhaps not a sufficient length of time to fix with accuracy a standard low-water, but as such a standard is constantly needed for the purpose of studying hydrographic maps, it seems proper to select one which shall be as near an approximation to the truth as present information will permit.

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I have procured from the records of the Saint Louis and Vicksburg Anchor Line Steamboat Company, and of the Merchants' Exchange of Saint Louis, the dates upon which navigation has been suspended on account of ice between Saint Louis and Cairo during the time covered by the reliable gauge record.

A convenient way to discuss these records is to assume some level as an approximate standard low-water and to compare this with them. A stage of 4' above the low-water of 1863 is assumed. The following table shows the year and the season when the river fell below this level, with its condition as regards ice at such times, the number of days during which it remained below the assumed standard when not closed by ice, and the lowest level which it reached :

Year.	Dates below 4-foot stage.	Number of days below 4-foot stage.	Dates when frozen.	Number of days frozen.	Number of days below 4-foot stage when not frozen.	Extreme distance below 4-foot stage.
1871	October 16 to November 11, November 20 to December 5, December 20 to December 26.	41	November 20 to December 5, December 20 to December 26.	14	27	Feet. 1.47
1872	January 15 to January 17, January 19 to January 30, November 24 to December 26.	48	January 24 to January 30, November 20 to December 4, December 12 to December 26.	28	20	21
1873	November 30 to December 2...	3	0	3	0.14
1874	December 30 and 31.....	2	December 30 and 31.....	2	0	
1875	January 1 to January 4, January 6 and 7.	6	January 1 to January 4, January 6 and 7.	6	0	
1876	None.....	.....	.....	.....	0
1877	None.....	0	0
1878	None.....	.....	.....	.....	0
1879	December 25 and 26.....	2	December 25 and 26.....	2	0	
1880	November 28 to December 2...	5	November 28 to December 2...	5	0	

It appears from this that during the last seven years, 1874 to 1880, the river has not fallen below the assumed standard at all, except when closed to navigation by ice, and in the preceding year, 1873, it was below it but three days, and then only fourteen-hundredths of a foot. If the record of the last eight years be alone considered, there can be no doubt that the assumed standard is quite low enough.

In 1872 the river was below the assumed standard for twenty days when not actually closed by ice. Seven of these days, December 5 to December 11, being preceded and followed by a frozen river, were not available for any heavy movement of freight.

During the eight days January 15 to 17 and January 19 to 23, the latter followed by a closure, the river must have been threatening and expected to close (it had been closed during the preceding month, December, 1871), so that the same remarks as to the movement of freight are applicable to these days. There is some doubt as to whether they are applicable to the five days remaining, November 24 to 28. The season was unusually early for a suspension of navigation, but at the same time the river rarely closes without several days' warning. During these five days the water surface was 0.13, 0.30, 0.50, 0.55, and 0.7 inch below the assumed standard, and the following day it was frozen. As freezing

over is nearly always preceded by heavy floating ice, which is itself a serious obstruction to navigation, it is thought that there is nothing in the record of 1872 to cast serious doubt upon the correctness of the assumed standard.

In 1871, however, twenty-seven days are found during the navigable season, October 16 to November 11, when the water surface was lower than this, and it is uncertain how many such days occurred previously to October 16. While this does cast a doubt upon the correctness of the standard, it is not conclusive against it. The record certainly does not show that the river is *likely* to fall below the assumed standard. So far as it extends it shows the reverse.

Ten years further observations will probably be required to settle this question with accuracy. For present purposes it is believed that a stage which marks 4 inches on the Saint Louis gauge may fairly be taken as a standard low-water. Works which will procure a channel depth of 8 feet at that stage may be regarded as providing for the present needs of commerce.

LOW-WATER DISCHARGE.

There has always been great difficulty in measuring the volume of discharge of the river at a very low stage, on account of the ice which is usually found at the season when the lowest water occurs. The value assigned to that quantity has been obtained by estimating from measurements taken at stages much higher than the low-water stage. From the nature of the stream this method gives only an approximation, which cannot be regarded as very close. On December last the river in front of Saint Louis became nearly free of ice, at a stage 4.45 feet above low-water of 1863, or 0.45 foot above what may, for the present, be considered standard low-water. A favorable opportunity being thus offered for measuring the discharge, at a stage much lower than any at which it had been previously measured, advantage was taken of it and the river was gauged. The discharge was found to be 47,800 cubic feet per second, at the stage, 4.45 feet, from which the discharge at a 4-foot stage, or standard low-water, is computed to be 47,000 cubic feet per second.

This work was done by my assistant, Mr. Wm. Popp, whose report, giving in detail the methods employed in taking the observations and making the computations, was forwarded to the department with my letter of January 6, 1881.

APPROPRIATION OF MARCH 3, 1881.

The allotments made from the appropriation of March 3, 1881, amounting to \$600,000, were for—

Twin Hollow and Widow Beard's	\$115,000 00
Cape Girardeau, Missouri, and Minton Point, Illinois	45,000 00
Repairs and contingencies	10,000 00
New plant	75,000 00
Surveys	5,400 00
Total	250,400 00

Which leaves a balance of \$349,600 available for beginning new works.

The allotment to Cape Girardeau was made on account of the special appropriation for that place which makes it necessary to keep there a force of assistants with a steamboat and other plant. The work is of a kind that requires constant watching. It is not safe to send a force there, expend the appropriation in a prompt and economical manner, and then disband or move elsewhere. Breaches are likely to occur in the brush obstacles, and these should be promptly repaired to prevent

serious damage. The special appropriation is not large enough to keep any considerable force at work during the entire season. At the same time, operations upon a small scale render the plant, particularly the steamboat, a very serious drain upon the appropriation. The works have a double object, viz, to provide convenient access to the Cape Girardeau landing, and to improve the general navigation of the river for several miles above. In their latter capacity they were thought to be a proper object of expenditure of the general fund, and it was accordingly decided to carry them on under both the special and general appropriations.

The distribution of the remaining \$349,600, or rather the survey undertaken with a view to preparing plans for its distribution, has been determined by the following considerations:

1st. The primary object of the improvement being to procure cheap through transportation for freight, the funds should be applied exclusively to such works as tend to deepen and maintain the present channel.

2d. The greatest benefit to the greatest number will be obtained by applying them below Saint Louis.

Vessels engaged in the trade above Saint Louis are, as a general rule, obliged to adapt their draught to what may be found in the Mississippi above the mouth of the Illinois, or in the Illinois or Missouri rivers. The channel depth between Saint Louis and the mouth of the Illinois is believed to compare favorably with that to be found in those rivers. At all events, the portion of the river lying between Saint Louis and Cairo is the one which carries the greatest amount of commerce, and is the part in which the deepening of the channel is most urgently required.

3d. The improvement should as far as practicable be continuous. The greatest economy in the use of plant and in administration can thus be obtained. The improvement of one section facilitates the improvement of the next. It is better, in the interest of navigation, that such obstacles as remain should be confined to one portion of the river than be distributed over all portions of it.

4th. It will not, as a general rule, be advisable to allot to any one locality funds sufficient to entirely complete its improvement with this appropriation. In nearly all cases two classes of works are required, viz, those to build up new banks, and those to preserve old banks, or revetments. The latter class are preservative, and do not usually afford relief from the obstructions now existing, there being an exception in the case of banks caving with great rapidity. The time required for their completion is dependent only upon the amount of means applied to them. Works of the first class are those which afford immediate relief to navigation. They form the first step in a process which will occupy many years, the number of which is uncertain; for the improvement can not be regarded as complete until the new banks have reached the height of the old ones. The first steps in this process are very rapid, and the last steps very slow. While the navigation will grow better and better each year until the process is completed, the greatest amount of benefit will be received at first. It would seem proper to obtain this immediate relief at as many places as possible, and afterwards, while the more tedious process of adding to the height of the reclaimed land is going on, to proceed with the revetment of the old banks. In all cases, therefore, when the rate of erosion does not exceed 20 feet a year, the revetments may for the present be postponed. More extended surveys are therefore required than would otherwise be necessary.

5th. It is desirable to work down stream from Saint Louis. In this

manner the channel is fixed as we progress, and its approach to the works below being known they can be properly designed to receive it. To work up stream leaves the channel free to approach the prepared bed in the manner designed for it, or to approach in some entirely different and unforeseen way.

Moreover, the channel depth obtained at first in the upper portion of the improved river is to a certain degree fictitious. It will be partially due to the pounding back of the water by the bars below, and as these are cleared out there will be a tendency to diminish the depth. At the same time the process of building up the new banks in the upper portion will be going on, and this tends to increase the depth. The removal of each bar, while tending to decrease the depth above, will increase that below. If the improvement be prosecuted from the lower end the first results will perhaps be locally greater than if it begin at the upper end, but they will be partially at the expense of the unimproved portion. In short, improvements below injure all above, while improvements above help all below. The most regular and uniform improvement of the entire section can therefore be obtained by working down stream.

Projects having been approved for the improvement of the river from Saint Louis to the mouth of the Meramec, 20 miles below the Saint Louis Bridge, the detailed hydrographic survey already alluded to was undertaken from that place to White Sand Depot, 51 miles below the bridge.

The foregoing assumes that the obstacles which exist or are likely to be formed between the mouth of the Meramec and Cairo do not vary largely among themselves in magnitude.

That this is the case is shown by the following table, in which are given the approximate distances below the Saint Louis Bridge of the localities where obstructions have been found in the last two years, with the least channel depth reported in 1879 and 1880:

Distance below Saint Louis bridge.	Interval.	Locality.	1879. °		1880.		Remarks.
			Least depth in channel.	Stage above low-water of 1863.	Least depth in channel.	Stage above low-water of 1863.	
Miles.	Miles.		Feet.	Feet.	Feet.	Feet.	
20½	4½	Jim Smith's	6	8.75	7	8.10	
25	2½	Foster's Island	8	8.75	5½	8.10	
27½	3½	Herculaneum	5	8.10	6	8.10	
31	2	Cornish Island	5½	.....	6½	10.58	
33	1½	Selina .....	.....	.....	6	8.10	
34½	1½	Forest Home	7	8.75	8	8.17	
36	12	Perry's Towhead	8	8.20	7	8.17	
48	7	Fort Chartres	7	8.75	6½	8.42	Brickey's Mills.
55	9	Sto. Genevieve Island	5	8.55	7½	8.10	Turkey Island.
64	5	Kaskaskia	4	6	8.17	
69	10½	Sto. Mary	6	8.17	
79½	4½	Sto. Mary's River	5	8.10	6	8.17	Cheehire.

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Distance below Saint Louis bridge.	Interval	Locality.	1879.		1880.		Remarks.
			Least depth in channel.	Stage above low-water of 1863.	Least depth in channel.	Stage above low-water of 1863.	
Miles.	Miles.		Feet.	Feet.	Feet.	Feet.	
84	5½	Liberty Island.....	5½	8.60	6	8.17	Grand Tower Gorge.
89½	9	Jones's Point.....	4½	8.75	5½	8.10	
98½	16	Hat Island	5	8.45	8	8.75	
114½	8	Crawford.....	5	8.10	6	8.17	
122½	5	Moccasin Spring	5½	8.10	5½	8.25	
127½	2½	Swift Shore Towhead.....	5½	8.20	6	8.10	
130	3½	Kinney Point	5½	8.55	8	8.17	
133½	3½	Devil's Islet (foot)	6	8.10	6	8.17	Commerce Gorge or Grand Chain.
137	15	Cape Girardeau	5½	8.10	5	8.17	
152	3	Jacket Pattern	5	8.10	6	8.17	
155	14	Goose Island	5½	.....	6	.....
169	3	Thompson's	6	.....	9	.....
172	6	Scudder Towhead	6	.....	10½	.....
178	2	Pond Lily	6	.....	5½	.....
180		Eliza Point.....	8	.....	5	.....

Of the twenty-seven localities enumerated nine are found within the limits to be covered by the detailed surveys. While some of these have been during the last two years of less magnitude than some of those below, the difference is not great enough to warrant a departure from the systematic method proposed; moreover, there is no certainty that the obstacles above will not be increased next year, while those below are diminished.

ESTIMATE FOR YEAR ENDING JUNE 30, 1883.

The amount given as that which can be profitably expended during the year ending June 30, 1883, is \$1,000,000. It is proposed to employ it in continuing the works to be begun this year, and in extending the improvement in accordance with the programme just described.

The plan is to make the improvement continuous, working down stream from Saint Louis, by reclaiming land and building up new banks, thus reducing the width of the river to the uniform width of about 2,500 feet. It is proposed by this means to secure a minimum depth of 8 feet. The depth is now liable to become as little as 4 feet in some places and less than 8 feet in every place where the width is greater than 2,500 feet.

Oaving banks are to be protected.

This general statement of the proposed application of the appropriation is as specific as the nature of the case will admit of. The changeable character of the river renders it impracticable to give in advance the exact localities where works will be required.

The work is located in the collection district of New Orleans.

Amount of revenue collected at the port of Saint Louis for the fiscal year ending June 30, 1881, was \$1,218,122.44.

Money statement.

July 1, 1880, amount available.....	\$283,338 57	
Amount appropriated by act approved March 3, 1881.....	600,000 00	
		\$883,338 57
July 1, 1881, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1880.....	231,395 81	
Amount re-appropriated by act of March 3, 1881, to be applied to harbor and Mississippi River at Alton.....	33,354 70	
July 1, 1881, outstanding liabilities.....	1,778 71	
		266,529 22
July 1, 1881, amount available.....		616,809 35
Amount (estimated) required for completion of existing project.....	5,539,420 32	
Amount that can be profitably expended in fiscal year ending June 30, 1883.....	1,000,000 00	

NOTE.—Amount re-appropriated by act of March 3, 1881, to be applied to harbor and Mississippi River at Alton, and amounts expended at Kaskaskia Bend are added to estimate of last year.

Construction Account.

Name of work.	Exp'd prior July 1, 1880.	Expended during fiscal year ending June 30, 1881.	Total to June 30, 1881.
Piasa Island Dam.....	\$32,383 30		\$32,383 30
Alton Dam.....	33,023 02		33,023 02
Sawyer's Bend protection.....	90,803 63		90,803 63
Venice dikes.....	30,341 85		30,341 85
Arsenal Island protection.....	0,673 85		0,673 85
Closing Cahokia chute.....	116,088 60		116,088 60
Horseshoe Bar, dike 1.....	40,549 53		40,549 53
Horseshoe Bar, dike 2.....	23,000 26		23,000 26
Horseshoe Bar, dike 3.....	82,602 54		82,602 54
Horseshoe Bar, dike 4.....	41,290 11		41,290 11
Horseshoe Bar, dike 5.....	36,933 87		36,933 87
Horseshoe Bar, training wall.....	80,627 03		80,627 03
Horseshoe Bar, primary hurdles, } Horseshoe Bar, secondary hurdles, }	89,757 57	\$116,078 53	205,836 10
Fort Chartres Dam.....	36,812 86		36,812 86
Turkey Island.....	24,463 85		24,463 85
Kaskaskia protection.....	54,130 28	12,326 34	66,456 62
Liberty Island dam.....	5,053 91		5,053 91
Liberty Island protection.....	45,129 40		45,129 40
Devil's Island, dike 1.....	65,871 17		65,871 17
Devil's Island, dam 1.....	49,848 58		49,848 58
Devil's Island, dam 2.....	16,678 30		16,678 30
Cairo Protection.....	113,351 43	6,517 23	119,868 66
Total.....	1,131,064 84	124,922 10	1,255,986 94

Property and material account.

Class of property.	Balance July 1, 1880.	Total debts.	Total credits.	Balance June 30, 1881.
Steamer A. A. Humphrey and expenses.....	\$14,210 64	\$25,628 26	\$20,924 13	\$18,914 77
Steamer Anita and expenses.....	3,595 48	6,691 54	5,435 04	4,851 97
Launch Hornet and expenses.....	105 71	1,300 40	1,300 40	105 71
Tug Mignon and expenses.....	4,212 72	386 63	521 63	4,077 72
Barges.....	20,000 24	65,241 03	13,090 10	71,320 17
Pile drivers.....	1,610 72	30,272 63	4,700 80	33,170 55
Quarters, shops, &c.....	7,495 37	13,332 88	5,383 20	15,445 05
Skills, flats, &c.....	401 24	2,009 74	700 00	1,704 98
Tools and appliances.....	1,805 01	4,100 81	1,500 00	4,411 82
Office furniture.....	224 05	283 65	65 75	441 95
Surveying instruments, &c.....	1,056 70	108 75	50 50	1,114 05
Material, stone, Little Rock.....	1,581 99			1,581 99
Material, stone, Saint Louis.....		6,220 57	6,220 57	
Material, piles, Saint Louis.....	915 50	42,768 08	42,562 80	1,121 68
Material, brush, Saint Louis.....		19,931 30	19,714 10	217 20
Material, miscellaneous.....		7,000 84	4,553 14	3,053 70
General expenses of property.....	23,282 45		23,282 45	
Total.....	80,626 82	231,959 10	150,085 71	161,600 21

1538 REPORT OF THE CHIEF OF ENGINEERS, U. S. ARMY.

Abstract of proposals for furnishing piles for Horsetail Bar, Mississippi River, received in response to advertisements dated August 9, 1880, and opened August 23, 1880, by Capt. O. H. Ernst, Corps of Engineers.

Number of proposal.	Names of bidders.	Residence.	Delivered at Horsetail Bar.						Amount.
			Cottonwood piles, per pile.						
			500	500	500	1,500	500	500	
			20 feet long.	23 feet long.	28 feet long.	30 feet long.	32 feet long.	34 feet long.	
*1	John Cleary.....	Chester, Ill.....							
12	W. Hughes.....	do.....							
*3	John W. Reno.....	do.....							
4	William K. Patrick.....	Saint Louis, Mo.....							
5	William McIntosh.....	Clarksville, Mo.....							
6	Martin Michael.....	Saint Louis, Mo.....	\$2 00	\$2 40	\$2 00	\$3 40	\$4 00	\$4 50	\$13,000
7	August Eyermann.....	do.....	3 10	3 10	3 10	3 10	3 10	3 10	12,400

Number of proposal.	Names of bidders.	Delivered at Horsetail Bar.					Delivered on government barges at landings within 100 miles of Saint Louis.						
		Hardwood piles, per pile.					Cottonwood piles, per pile.						
		300	300	300	200	Amount.	500	500	500	1500	500	500	Amount.
		40 feet long.	44 feet long.	48 feet long.	52 feet long.		20 feet long.	24 feet long.	28 feet long.	30 feet long.	32 feet long.	34 feet long.	
*1	John Cleary.....						\$1 00	\$1 20	\$1 40	\$1 50	\$1 70	\$1 00	\$5,850
+2	W. Hughes.....						1 00	1 20	1 45	1 00	2 00	2 20	6,325
+3	John W. Reno.....						1 20	1 44	1 08	1 80	1 92	2 04	6,840
4	William K. Patrick.....						1 15	1 35	1 00	1 75	1 90	2 00	6,625
5	William McIntosh.....						3 00	3 00	4 20	4 50	4 80	5 10	17,100
6	Martin Michael.....	\$5 00	\$5 60	\$6 20	\$7 00	\$6,440							
7	August Eyermann.....	6 50	6 50	6 50	6 50	7,150							

Number of proposal.	Names of bidders.	Delivered on government barges at landings within 100 miles of Saint Louis.					Location of landing.
		Hardwood piles, per pile.					
		300	300	300	200	Amount.	
		40 feet long.	44 feet long.	48 feet long.	52 feet long.		
*1	John Cleary.....	\$2 00	\$2 85	\$3 12	\$3 38	\$3,247	Chester, Ill., and Ste. Genevieve, Mo.
12	W. Hughes	2 50	2 80	3 25	3 05	3,295	Not stated.
*3	John W. Reno.....	2 80	3 52	3 84	5 20	4,088	Clearyville and Chester, Ill., and Ste. Genevieve, Mo.
4	William K. Patrick	3 20	3 06	4 80	5 72	4,732	Liberty Island, Mississippi River, Missouri shore.
5	William McIntosh	7 20	7 02	8 64	9 36	9,000	Clarksville, Mo., and above mouth of the Missouri River.
6	Martin Michael .....	.....	.....	.....	.....	.....
7	August Eyermann .....	.....	.....	.....	.....	.....

* Not in duplicate. † Presumed to be from W. Hughes. Bid not signed nor bond executed.

APPENDIX R.

1539

Abstract of proposal for building and delivering at Saint Louis, Mo., three barges for improvement of the Mississippi River, received in response to advertisement dated September 7, and opened October 2, 1880, by Capt. O. H. Ernst, Corps of Engineers.

Number of proposal.	Name of bidder.	Residence.	Price for three barges.
1	William Jones	New Albany, Ind.....	\$15,400

A Record of gauge at Grafton, Ill., for the fiscal year ending June 30, 1881.

[Height of water above a plane 200 feet below the Saint Louis City directrix.]

Day.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
1	208.81	189.36	195.64	197.64	194.70	185.50	195.45	194.60	199.50	200.00	213.88	204.55
2	09.21	09.06	05.75	08.20	04.00	05.75	05.00	04.68	200.10	06.95	14.02	04.10
3	09.68	08.76	05.80	08.72	04.60	05.44	05.74	04.50	199.75	07.10	14.05	03.82
4	09.76	08.46	06.00	08.85	04.60	05.40	05.74	04.52	09.30	07.44	14.18	03.50
5	09.86	08.16	06.15	08.80	04.08	05.45	05.50	04.00	09.62	07.64	14.25	03.20
6	10.21	07.86	06.42	08.30	04.70	05.80	05.40	05.06	09.80	07.05	14.10	03.50
7	10.31	07.68	06.65	07.95	04.62	05.95	05.32	05.55	200.05	07.88	13.70	02.75
8	10.41	07.52	06.90	07.60	04.82	05.72	05.20	05.80	200.00	08.50	12.00	02.55
9	10.41	07.46	07.15	07.30	04.85	05.20	05.16	07.35	199.95	08.90	11.95	02.74
10	10.31	07.31	07.32	07.00	04.75	05.35	04.90	09.55	200.00	09.10	10.80	03.02
11	10.11	07.12	07.30	06.74	04.80	05.75	04.80	200.80	00.20	09.40	10.02	03.32
12	09.76	06.60	07.06	06.50	04.85	05.90	04.70	01.15	01.52	09.05	09.20	03.65
13	09.68	06.34	06.85	06.15	04.80	06.02	04.70	01.20	02.60	09.85	08.02	04.05
14	09.21	06.10	06.00	05.04	04.80	06.30	04.70	00.75	03.55	09.95	08.75	04.40
15	08.71	05.00	06.25	05.70	04.82	06.30	04.68	00.40	03.50	10.00	08.50	04.65
16	07.76	05.08	06.00	05.45	05.05	06.42	04.05	199.90	03.70	10.00	08.50	05.00
17	07.36	05.45	05.70	05.20	05.10	06.30	04.62	09.50	04.05	10.00	08.52	05.35
18	06.46	05.30	05.45	04.86	05.20	06.28	04.60	09.30	04.04	00.90	08.70	05.70
19	05.61	05.25	05.35	04.72	05.02	05.78	04.70	09.02	04.20	00.80	08.85	06.05
20	04.81	05.20	05.25	04.70	04.75	05.08	04.74	08.85	04.40	09.85	09.00	06.35
21	04.02	05.00	04.05	04.85	04.60	04.75	04.74	08.80	04.04	10.10	09.02	06.65
22	03.40	04.80	05.04	05.20	04.35	04.86	04.74	08.50	03.62	10.50	08.00	06.90
23	02.80	04.78	05.35	05.35	04.50	04.90	04.05	08.70	03.40	11.00	08.80	07.25
24	02.20	04.70	05.60	05.16	03.80	04.00	04.60	08.75	03.30	11.70	08.70	07.55
25	01.81	04.62	06.05	05.00	03.50	04.00	04.60	08.45	03.40	12.32	08.45	07.65
26	01.36	04.50	06.30	05.04	03.42	04.00	04.55	08.40	03.60	12.85	08.50	07.40
27	00.96	04.48	06.25	05.00	03.20	05.00	04.50	07.80	03.85	13.25	07.55	06.90
28	00.56	04.62	06.02	04.62	03.25	04.75	04.50	08.50	04.15	13.70	06.84	06.45
29	00.28	04.95	06.05	04.90	03.58	04.00	04.50	.....	04.85	13.80	06.20	06.05
30	09.96	05.25	06.95	04.80	04.82	04.05	04.48	.....	05.00	13.88	05.65	05.90
31	09.60	05.40	.....	04.75	.....	05.35	04.55	.....	06.10	.....	04.94	.....

* Ice gorged half mile below, November 30. Navigation was suspended on account of ice November 17, and remained so to February 26. Highest stages 214.25 feet, May 5. Lowest stages 193.20 feet November 29.

1540 REPORT OF THE CHIEF OF ENGINEERS, U. S. ARMY.

B.—Record of gauge at Alton, Ill., for the fiscal year ending June 30, 1831.

(Height of water above a plane 200 feet below the Saint Louis City directrix.)

Day.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
1	201.05	193.18	189.32	180.30	187.65	188.88	187.06	187.82	103.23	201.95	209.05	108.08
2	02.25	92.73	89.55	90.85	87.60	89.00	88.20	87.80	94.05	02.30	09.55	97.67
3	02.08	92.33	90.10	91.35	87.68	88.95	88.35	87.77	94.00	02.23	10.12	97.55
4	02.85	92.08	90.80	91.53	87.58	89.10	88.30	87.85	93.80	02.50	10.55	97.75
5	03.40	91.83	90.45	91.42	87.65	89.39	88.25	87.90	93.83	02.38	10.72	97.68
6	03.70	91.60	90.35	91.05	87.65	88.70	88.20	87.85	93.80	01.07	10.55	97.85
7	03.80	91.40	90.75	90.85	87.57	88.20	88.17	88.35	93.08	02.25	09.04	97.47
8	03.85	91.30	91.32	90.65	87.55	88.24	88.12	88.72	94.01	03.25	08.55	97.20
9	03.93	91.20	91.85	90.30	87.50	88.15	88.15	90.90	93.70	03.70	08.08	97.10
10	03.95	91.10	92.00	89.92	87.75	88.15	88.20	95.10	93.58	03.33	05.33	97.25
11	03.90	90.85	91.65	89.68	87.75	88.62	88.05	95.44	93.50	03.05	04.25	97.35
12	03.75	90.65	91.20	89.40	87.75	88.35	88.00	95.40	94.55	04.25	03.50	97.73
13	03.50	90.40	90.55	89.20	87.70	89.01	87.81	95.20	90.30	04.65	03.28	98.28
14	03.15	90.20	90.20	88.03	87.70	89.30	88.20	94.09	97.50	05.00	03.05	98.87
15	02.85	90.00	89.85	88.70	87.75	89.58	88.26	93.89	97.80	05.25	02.72	98.85
16	02.35	89.75	89.50	88.50	87.95	89.72	88.20	93.38	98.05	05.30	02.35	98.95
17	01.00	89.45	89.20	88.30	88.20	89.81	88.23	92.00	98.65	05.25	02.35	99.28
18	00.80	89.30	88.95	88.02	88.12	89.40	88.30	92.40	99.40	04.85	02.30	99.62
19	00.05	89.05	88.83	87.85	87.90	88.98	88.20	91.98	99.70	04.20	02.40	200.35
20	199.10	88.83	88.63	87.85	87.00	88.69	88.20	91.05	99.70	03.95	02.45	00.93
21	98.40	88.05	88.42	87.02	87.55	88.20	88.20	91.52	99.13	04.03	02.40	01.08
22	07.80	88.46	88.41	88.15	87.25	88.30	88.15	91.15	98.00	04.48	02.28	01.07
23	07.25	88.35	88.59	88.33	87.12	88.08	88.13	91.13	98.10	05.28	02.14	01.22
24	06.73	88.28	88.70	88.20	86.60	88.15	88.05	91.23	97.05	06.15	02.08	01.34
25	06.30	88.22	89.03	88.15	85.50	88.05	87.98	91.10	98.10	06.00	02.18	01.45
26	05.98	88.10	89.30	88.10	85.30	87.90	87.96	90.95	98.43	07.46	01.98	01.27
27	05.42	88.08	89.33	88.05	86.30*	87.70	87.05	91.30	98.45	07.90	01.48	00.78
28	04.40	88.10	89.15	88.02	87.85	86.65	87.90	91.89	98.55	08.30	00.70	00.38
29	03.80	88.63	89.05	87.95	88.50	86.45	87.87	.....	98.80	08.55	190.00	00.00
30	03.30	89.15	89.70	87.85	88.65	87.25	87.70	.....	99.50	08.75	99.17	109.68
31	02.93	89.20	.....	87.75	.....	87.75	87.75	.....	200.65	.....	98.00	.....

* Ice gorgo below November 27. Navigation was suspended on account of ice from November 20 to February 26. Highest stage, 210.72 feet, May 5. Lowest stage, 185.30 feet, November 20.

RIVER AND HARBOR IMPROVEMENTS.

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During the coming season it is proposed to continue this improvement on the same general plan from Longview to the mouth of the river, completing the work as far as the funds available will allow.

July 1, 1881, amount available.....	\$8,637 26
July 1, 1882, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1881.....	6,162 94
July 1, 1882, amount available.....	2,474 32
Amount appropriated by act passed August 2, 1882.....	4,000 00
Amount available for fiscal year ending June 30, 1883.....	6,474 32
Amount that can be profitably expended in fiscal year ending June 30, 1884..	10,000 00
(See Appendix Q 11.)	

12. *Current River, Missouri and Arkansas.*—The project for improving the navigation of this stream is by means of wing-dams of brush and stone to concentrate the water over the shoal places, and to remove the snags, logs, and overhanging trees. With the amount available for the work during last season, 180 snags were removed and about 3,000 overhanging trees cut down. Operations were commenced at the mouth and carried up the river an estimated distance of about 50 miles.

With the funds that may be made available for the next season's work, it is proposed to carry out the general project for the improvement as far as they will suffice.

July 1, 1881, amount available.....	\$2,000 00
July 1, 1882, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1881.....	1,465 17
July 1, 1882, amount available.....	534 83
Amount that can be profitably expended in fiscal year ending June 30, 1884..	10,000 00
(See Appendix Q 12.)	

EXAMINATIONS AND SURVEYS FOR IMPROVEMENT.

To comply with the provisions of the river and harbor act approved March 3, 1881, Captain Handbury was charged with and has completed the following, which was transmitted to Congress and printed as Senate Ex. Doc. No. 32, Forty-sixth Congress, first session.

Little Red River, Arkansas. (See also Appendix Q 13.)

IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVER—IMPROVING HARBOR AND MISSISSIPPI RIVER AT ALTON—ICE HARBOR AT SAINT LOUIS, MISSOURI—IMPROVING MISSISSIPPI RIVER AT OR NEAR CAPE GIRARDEAU, MISSOURI, AND MINTON POINT, ILLINOIS—IMPROVEMENT OF OSAGE RIVER IN KANSAS AND MISSOURI.

Officer in charge, Maj. O. H. Ernst, Corps of Engineers, having under his immediate orders First Lieut. F. V. Abbot, Corp of Engineers, since June 10.

1. *Mississippi River, between the Illinois and Ohio rivers.*—Work was carried on at the Supply Depot, Arsenal Island, Horsetail, Carroll's Island, Twin Hollows, west bank, Twin Hollows, east bank, Beard's Island, and "Jim Smith's."

Supply Depot.—A piece of ground belonging to the United States within the limits of the city of Saint Louis was occupied as a supply depot. The necessary shops and store-rooms were erected, and im-

provements were made in the landing on the river side. The expenditures were \$7,494.32.

Arsenal Island.—The project for the improvement of this locality was adopted in 1876, its object being to stop the erosion of the west side of Arsenal Island, and the consequent deterioration of the navigation. The amount expended during the year was \$14,513.88. The total amount expended to June 30, 1882, is \$24,187.73, and has resulted in the partial protection of 7,525 feet of bank, of which 4,450 feet was completed.

It is proposed to extend the protection to the foot of the island, a distance of about 300 feet, and to complete the portion already begun.

Horsetail.—The present project for the improvement of this locality was adopted in 1873 and modified in 1879, the object being to afford a channel not less than 8 feet deep.

The natural channel was often not more than 4 feet in depth at the shoalest part, and was tortuous. The amount expended during the year was \$98,553.23. The total amount expended to June 30, 1882, is \$610,082.67, of which, however, but \$304,389.33 has been employed upon the system adopted in 1879. It has resulted in securing a direct navigable channel with a depth not less than 8½ feet. Further work will be required to preserve these results, the amount of which is a matter of future contingency.

Carroll's Island.—The present project for the improvement of this locality was adopted in 1881, the object being to protect the west side of Carroll's Island near its down-stream end from caving and the consequent deterioration of the navigation. Before the work was begun the caving was going on at the rate of several feet per day. The amount expended during the year, which includes all expenditures to June 30, 1882, was \$12,038.69, and has resulted in stopping the erosion over a length of 1,695 feet of bank. No further work here will be required unless changes in the direction of the channel above should occur in the future.

Twin Hollows, west bank.—The present project for the improvement of this locality was adopted in 1881, the object being to afford a channel not less than 8 feet deep. The natural channel was often not more than 4 feet deep in the shoalest parts. The amount expended during the year, which includes all expenditures to June 30, 1882, was \$103,500.25. The works have not advanced sufficiently far to have any effect upon the channel. It is intended during the coming year to push them forward as rapidly as can be done without interfering with navigation, but it is not expected that much more can be accomplished during the coming year than to straighten the channel without materially deepening it.

Twin Hollows, east bank.—The present project for the improvement of this locality was adopted in 1881, the object being to stop the caving which extended over a length of 8,400 feet of the bank and the consequent deterioration of the navigation. Before the work was begun the caving was progressing at the rate of several feet per day. The amount expended during the year, which includes all expenditures to June 30, 1882, was \$72,696.63, and has resulted in stopping the caving over a length of 5,925 feet of the bank. In this distance the work has been completed for a length of 2,350 feet. It is proposed during the coming year to complete the portions already begun and to extend the protection 2,475 feet down-stream.

Beard's Island.—The present project for the improvement of this locality was adopted in 1881, the object being to close a small chute north of the island, and to stop the erosion of the west side of the island and the consequent deterioration of navigation. Before the work was be-

gun the caving was progressing at the rate of several feet per day and the water in the chute was 40 feet deep. The amount expended during the year, which includes all expenditures up to June 30, 1882, was \$35,014.53, and has resulted in closing the chute and stopping the caving for a distance of 3,550 feet of the bank, over about half of which the work is not entirely completed. It is proposed during the coming year to complete the portion already begun and to extend the protection to the foot of the island, a distance of about 3,950 feet.

"Jim Smith's."—The present project for the improvement of this locality was adopted in 1881, the object being to afford a channel not less than 8 feet deep. The natural channel was often not more than 4 feet deep in the shoalest parts.

The amount expended during the year, which includes all expenditures up to June 30, 1882, was \$11,068.37. The works have not advanced sufficiently far to have any effect upon the channel.

Estimate.—The appropriation of \$1,000,000 asked for is to be applied to completing the works now progressing and to beginning new works below Foster's Island. From the changeable nature of the stream it is not practicable to give in advance the names of the exact localities where work will be required. The programme is to make the improvement continuous, working down-stream from Saint Louis, by reclaiming land and building up new banks, thus reducing the width of the river to the uniform width of about 2,500 feet. Caving banks are to be protected. The appropriation of the above sum is recommended.

July 1, 1881, amount available.....	\$616,809 35
July 1, 1882, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1881.....	\$466,168 88
July 1, 1882, outstanding liabilities.....	38,495 29
	<hr/> 504,664 17

July 1, 1882, amount available.....	112,145 18
Amount appropriated by act passed August 2, 1882.....	600,000 00

Amount available for fiscal year ending June 30, 1883.....	<hr/> 712,145 18
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Amount (estimated) required for completion of existing project*.....	5,094,288 98
Amount that can be profitably expended in fiscal year ending June 30, 1884.†	1,000,000 00

(See Appendix R I.)

2. *Harbor and Mississippi River at Alton.*—The present project for the improvement of this harbor was adopted in 1881, the object being to remove a shoal in front of the down-stream portion of the landing. The amount expended during the year, which included all expenditures up to June 30, 1882, was \$33,324.70. The work has not had time to exert any great effect upon the shoal, and it has not extended far enough to be of great benefit. The appropriation of \$16,700 asked for is to be applied to raising and extending the dike opposite and above the town.

July 1, 1881, amount available.....	\$33,324 70
July 1, 1882, amount expended during fiscal year exclusive of outstanding liabilities July, 1881.....	33,324 70
Amount (estimated) required for completion of existing project.....	51,675 30
Amount that can be profitably expended in fiscal year ending June 30 1884†	16,700 00

(See Appendix R 2.)

* Estimate of last year increased by amount previously expended between Dickey's Island and mouth of Ohio, and by amount allotted to Alton Harbor by act of August 2, 1882.

† Estimate of last year diminished by \$35,000 the amount allotted by Congress from appropriation of August 2, 1882, for improving Mississippi River from Cairo to the Illinois River.

3. *Ice Harbor at Saint Louis, Missouri.*—This work has not been begun, the funds being held until further action by Congress. The act of August 2, 1882, transfers the appropriations to the title of "Improvement of the channel of the Mississippi River opposite the city of Saint Louis, Missouri." They will hereafter be accounted for under that title. It is proposed with them to raise the present submergible dam across Cahokia Chute, and to complete the protection of the west side of Arsenal Island. It is thought that they will be sufficient to accomplish what is required for the present, and no additional appropriation is asked for

July 1, 1881, amount available	\$60,000 00
July 1, 1882, amount available	60,000 00

(See Appendix R 3.)

4. *Mississippi River at or near Cape Girardeau, Missouri, and Minton Point, Illinois.*—The present project for the improvement of this locality was adopted in 1881, the object being to remove a large and growing bar in front of the Cape Girardeau Landing and to provide an 8-foot channel between that place and Minton Point. The bar was dry at a stage of 16 feet above low-water, and the channel depth was liable to be as little as 4 feet. The amount expended during the year, which included all expenditures to June 30, 1882, was \$43,529.96 of which \$18,350.12 was added to the special appropriation from the funds provided for improving Mississippi River between Illinois and Ohio rivers, and has resulted in wholly removing the bar and increasing the navigable depth above.

The appropriation of \$42,000 asked for is to be applied to perpetuating these results by protecting the banks.

July 1, 1881, amount available	\$25,179 84
July 1, 1882, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1881	25,179 84
Amount (estimated) required for completion of existing project	41,820 04
Amount that can be profitably expended in fiscal year ending June 30, 1884	42,000 00

(See Appendix R 4.)

5. *Osage River, Kansas and Missouri, below Tuscumbia.*—The present system of improvement employed below Tuscumbia was begun in 1871, the object being to afford a channel of navigable width not less than 2 feet deep.

The natural channel was frequently not more than 6 inches deep at many of the shoals. The amount expended during the year was \$9,696.96. The total amount expended to June 30, 1882, is \$167,870.57, and has resulted in increasing the depth to at least 2 feet over 21 shoals, and removing all snags and overhanging trees.

Above Tuscumbia.—The project for the improvement of the Osage above Tuscumbia was adopted in 1881, the object being to remove all snags and overhanging trees which obstructed navigation. In the natural state of the river many hundreds of these obstructions existed. The amount expended during the year, which includes all expenditures up to June 30, 1882, was \$10,759.36, and has resulted in clearing the natural channel as high up as Warsaw, a distance of 176 miles from the mouth. Funds on hand will be sufficient to repeat as much of this work as may be required during the present year and to extend it to Osceola, the head of navigation, 230½ miles from the mouth. The appropriation of \$5,000 asked for is to be applied to the removal of the new supply of these obstacles which is to be expected.

* Estimate of last year diminished by amount allotted from funds appropriated for improving Mississippi River between Illinois and Ohio rivers.

APPENDIX R.

IMPROVEMENT OF MISSISSIPPI RIVER BETWEEN THE MOUTHS OF THE ILLINOIS AND OHIO RIVERS—IMPROVING HARBOR AND MISSISSIPPI RIVER AT ALTON—ICE-HARBOR AT SAINT LOUIS, MISSOURI—IMPROVING MISSISSIPPI RIVER AT OR NEAR CAPE GIRARDEAU, MISSOURI, AND MINTON POINT, ILLINOIS—IMPROVEMENT OF OSAGE RIVER IN ARKANSAS AND MISSOURI.

REPORT OF MAJOR O. H. ERNST, CORPS OF ENGINEERS, OFFICER IN CHARGE, FOR THE FISCAL YEAR ENDING JUNE 30, 1882, WITH OTHER DOCUMENTS RELATING TO THE WORKS.

IMPROVEMENTS.

- | | |
|---|---|
| 1. Mississippi River, between the Illinois and Ohio rivers. | 4. Mississippi River at or near Cape Girardeau, Missouri, and Minton's Point, Illinois. |
| 2. Harbor and Mississippi River at Alton. | 5. Osage River, Kansas and Missouri. |
| 3. Ice-harbor at Saint Louis. | |

EXAMINATIONS AND SURVEYS.

6. Fish Bend near Fort Chartres, in the Mississippi River.

UNITED STATES ENGINEER OFFICE,
Saint Louis, Mo., August 24, 1882.

GENERAL: I have the honor to transmit herewith the annual reports for the fiscal year ending June 30, 1882, upon the works under my charge.

Very respectfully, your obedient servant,

O. H. ERNST,
Major of Engineers.

Brig. Gen. H. G. WRIGHT,
Chief of Engineers, U. S. A.

R 1.

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

In carrying out the programme, definitely adopted last year, of making the improvement continuous, working downstream from Saint Louis, work has been carried on during the year at Arsenal Island, Horsetail, Carroll's Island, Twin Hollows, west bank, Twin Hollows, east bank, Beard's Island, and "Jim Smith's."

1592 REPORT OF THE CHIEF OF ENGINEERS, U. S. ARMY.

Plate I is a general map of the river between the Saint Louis bridge and Kimmswick, a distance of 22 miles, which shows the location of these places.

ORGANIZATION.

To provide for the enlarged operations of the latter half of the year it became necessary to reorganize the administrative staff. A superintending engineer was assigned to the general supervision of all the works and of the supply depot, while at each locality there was stationed a resident engineer with one or more assistants. The superintending engineer had his office in Saint Louis and was in almost daily consultation with myself. His prescribed duties were to advise and direct the resident engineers and to have special charge of the procurement of brush and stone, and of the tow-boat and barges engaged in that work. The resident engineer was provided with quarters and an office at the work. His prescribed duties were to have immediate direction of the work of construction, to make such surveys and observations as might be required to keep the progress map upon which all work was to be located as fast as constructed; to keep the journal and other records of the work; to prepare the pay-rolls; to render the quarterly property returns; to make requisitions for material required and reports of material received; to supervise the kitchens, mess-rooms, and quarters; and to render the weekly, monthly, semi-annual, and annual reports to the officer in charge, required by existing regulations, forwarding them through the superintending engineer. He was aided in these duties by assistants whose number depended upon the magnitude of the work. Notwithstanding the fact that the organization was new and many of the assistants were without experience, it has worked with great smoothness. The works have made good progress, a minute record has been kept of exactly where and how each kind of work was being done and what it was costing, and a force of about 1,100 men has been cared for in a country destitute of shelter and supplies, while one tow-boat sufficed to supply all the works.

A few changes in the assignments were made after the season opened. At the end of the year they were as follows, viz:

Superintending engineer, Mr. D. M. Currie.

Resident engineers:

At Arsenal Island and Horsetail, Mr. A. Freis, assisted by Mr. J. L. Stubblefield.

At Carroll's Island, Mr. C. V. Mersereau.

At Twin Hollows, east bank, Mr. C. V. Mersereau, assisted by Mr. A. W. Chase and Mr. J. W. Irwin.

At Twin Hollows, west bank, Mr. W. S. Mitchell, assisted by Mr. John L. Duffy and Mr. S. B. Cady.

At Beard's Island, Mr. J. W. Record, assisted by Mr. J. E. Savage.

At "Jim Smith's," Mr. John O. Holman, assisted by Mr. E. D. Libby and Mr. B. E. Johnson.

At the supply depot, Mr. S. S. Van Norman had charge of the subsistence department, and Mr. O. L. Stevenson, of the engineering supplies and repairs.

On board the steamer Humphreys, Mr. O. P. Mitchell acted as general receiver of materials and measured the brush and stone.

The reports of Mr. D. M. Currie and of the resident engineers are herewith transmitted, and are intended to form part of this report. They constitute Appendixes A, B, C, D, E, F, G, H, and I, of this re-

port. They give so fully all the details of the works, that but little more will be required here than to give the reasons for each work and its results, so far as they have as yet been attained.

While all of these gentlemen have shown great intelligence and zeal in the discharge of their duties, the services of Mr. Currie have been of exceptional value.

First Lieut. F. V. Abbot, Corps of Engineers, reported to me for duty just before the close of the fiscal year, and was assigned to the study of special questions of great importance in the economical prosecution of the works.

SUPPLY DEPOT.

Under the authority of the honorable Secretary of War, dated January 4, 1882, the strip of ground cut off from the old arsenal grounds in this city by the Iron Mountain Railway, and lying between the railway and the river, was taken possession of by the Engineer Department, to be used as a depot of supplies for the works under my charge.

The authority for occupying the ground was given with the following condition:

But it should be distinctly understood that the Quartermaster Department for the landing and shipment of supplies at the depot shall retain its present rights and privileges thereon. This right may, in case of extensive military operations, become very important to the economical handling of supplies for troops.

The necessary shops and store-rooms were immediately erected (see Appendix I), and improvements were made in the landing with a view to facilitating shipments. With the latter object the retaining wall which obstructed communication with the river was partially demolished, the wall being cut down 6 feet from the top over a portion of its length; and a hurdle was run out into the river to cause deposits in front of the wall. The object of both pieces of work was to finally secure an inclined plane of gentle slope, against which boats can land at all stages.

The establishment of this depot has rendered it possible to make purchases upon favorable terms, and to supply the works with regularity and at a minimum cost both for materials and transportation. It has given also much needed facilities for fitting out and repairing the equipment.

The expenditures upon the depot itself were \$7,494.32.

ARSENAL ISLAND PROTECTION.

The first shoal which formerly existed below the Saint Louis Bridge was at the head of Arsenal Island, and the second one at the foot of the same island. The submergible dam thrown across the East Chute, or Cahokia Chute (see Plate I), in 1878 and 1879, has removed both of these shoals, there having been not less than 9 feet of water upon either of them at the lowest stage reached during the past year. The enlarged volume of water thrown into the West Chute rendered it necessary torevet the west side of the island. Simultaneously with the construction of the dam, the protection was begun at the upstream end of the island, the downstream portion being left unprotected in order to allow the chute to widen out to the full width of 1,500 feet, the width adopted for the part of the river lying within the limits of Saint Louis. The protection was extended downstream at intervals as the erosion reached the desired limit. The work this year has been to still further extend it.

At the beginning of the year the work had been completed to the point A (Plate II), a distance of 950 feet from the head of the island. A

partial revetment had been placed from A to B, a distance of 3,500 feet, but only the portion below a level 7 feet above standard low water had been constructed, the upper portion of the bank having been left unprotected until it should be graded to a gentle slope by the action of the river. This grading having been accomplished, the work of completing the revetment by extending it up the bank was begun in November last. A layer of riprap about 1 foot thick was placed upon the bank, completing the protection to a height of 16 feet above standard low water.

The old protection having been completed, the work of extending it downstream was begun this spring. The flow of the stream here being parallel to the bank, it was not considered necessary to extend the protection to the great width below low water required in other circumstances. Mattresses 40 feet wide were placed below low water mark for a length of 2,750 feet, C to D. Just below the old work there was an indentation, B C, 325 feet long, in the shore, which it was thought best to fill up in order to give it a smoother outline. To accomplish this three short hurdles were constructed.

To complete this work there remain to place the footing mattress for a length of about 625 feet, and to deposit riprap upon the bank above low water for a length of 3,375 feet.

The expenditures were \$14,513.88.

HORSETAIL.

The third, fourth, and fifth shoals below Saint Louis were found in the reach known as Horsetail. The works for the improvement of this locality have been under way for a number of years, and have been fully described in former reports. They have for their object to contract the river to a width of about 2,500 feet by reclaiming land and building up new banks, and, as the result of such contraction, to obtain a low water depth of at least 8 feet. They are shown on Plate III, which, when compared with Plate II of my last annual report, shows the progress made during the year. On the Illinois side the primary hurdle was extended downstream until it reached shoal water, the unfinished secondary hurdles were extended to intersect the primary one, and an additional secondary hurdle, No. 30, was constructed. On the Missouri side the primary hurdle was begun and extended downstream as far as was considered necessary, and the secondary hurdles were completed.

The prolonged high water of last autumn and this spring has caused numerous small breaks in the hurdles, many of which it has not been considered necessary to repair, on account of the heavy deposits which had already been secured. In reconstructions and repairs a more substantial form of construction is employed than that used at first.

The high water which has continued during the greater part of the year has prevented the growth of willows at the lower levels and the consequent consolidation of the new-made land. At the lower end of the reach there has been some loss, but upon the whole the process of building up the new banks has continued in a satisfactory manner. It is difficult to show this clearly upon a map small enough to be suitable for publication. Plate III shows the deposits as they appear at a 15-foot stage, and Plate IV as they appear at a 12-foot stage, Saint Louis gauge. On the latter plate the outline of the bars, as they appeared at the beginning of the year as well as at the end, is given. On the Illinois side almost the entire area above hurdle No. 15 has reached a height

of more than 20 feet above low water of 1863, many acres of it being more than 25 feet. The same may be said of the Missouri side above No. 6. The heavier deposits secured during the year upon the Missouri side are due to the fact that upon that side of the river the water is at all seasons from the Missouri River, while on the Illinois side the water is often from the Upper Mississippi, almost undiluted.

The beneficial effect upon the channel has been very marked. Of the three principal reefs which were prominent last year the first and third had entirely disappeared when the water fell in August, 1881, there being a low water depth of from 15 to 30 feet at the places where they were found. During the short low water season of last August the middle reef assumed a troublesome form, its Missouri end retaining nearly its former position, but its Illinois end swinging down stream so as to give it a total length of nearly 2 miles. There were three depressions or channels through it, the depth of water in the one followed by steamboats being sometimes equal to and sometimes less than that in the others. A depth of but 6 feet having been reached in the channel usually followed by steamboats, it was decided to deepen it in order to aid the river to concentrate. The water jet was applied with remarkably great and prompt results (see Appendix A), an additional depth of $2\frac{1}{2}$ feet being gained in ten hours' work. On the 12th of August, 1882, with the river at a stage $11\frac{1}{2}$ feet above standard low water, there was a least channel depth of 20 feet throughout the Horsetail Reach, the channel being direct and wide. This would give a depth of $8\frac{1}{2}$ feet at low water, supposing that the bottom does not scour as the river falls, as it usually does. But a better idea may be obtained of the result by comparing this depth with that found on the same day upon other bars between Saint Louis and Cairo. The depths reported by the pilots of the steamer City of Helena were 8 feet upon three bars, 12 feet or less upon eight others, and 15 feet or less upon seven others.

The result sought for at this place has therefore been attained. But it must not be understood that the work is finished. Before the new deposits can be regarded as secure, they must be protected both on top and on the channel sides. The protection on top will consist of a growth of willows, which, it is thought, can be obtained without expense by spontaneous growth. A considerable area has not yet reached a height at which the willow will grow. The hurdles must be kept in repair, and possibly additional ones constructed until such a height is reached. The amount of protection that will be required on the channel side is a matter of future contingency. The lower portions of the deposits are protected by the lower parts of the piles and the mattress-work placed in connection with them, but the vertical face presented by the hurdle does not offer a good protection for the upper portions. It will sooner or later be destroyed by ice or by decay. For considerable distances deposits have already been made outside the works, and it seems probable that as the channel settles down in one well-defined location away from the works these outside deposits will be extended. In such cases no further protection will be required. But where the water-way at low and medium stages remains permanently in contact with the work, it will be necessary to replace the primary hurdle by a layer of riprap deposited upon the slope of the new bank. It is possible that the time for work of this kind has arrived for the Missouri side, but that cannot be determined until the river has reached a lower stage than the present. For the Illinois side, it is thought that it should be deferred for at least another year.

The expenditures at Horsetail were \$98,553.23.

CARROLL'S ISLAND PROTECTION.

After the high water of July, 1881, the channel was found crossing from the Missouri shore to the foot of Carroll's Island, which it was rapidly undermining and washing away. It was necessary to protect the west side of the island near its lower end. The case presented was one analogous to that of a caving bend, where the direction of attack of the stream is at an angle with the bank; the width of protection below low water for such cases was fixed at 120 feet. The details of construction designed to meet these cases are shown on Plate XIV, and will be described further on. A single mattress, 120 feet wide and 1,605 feet long, was constructed and placed in position, as shown on Plate X.

The extension of the revetment up the bank was rendered unnecessary by a heavy deposit outside of it, which occurred during the high-water of November.

The expenditures here were \$12,038.69.

TWIN HOLLOW, WEST BANK.

The locality known as Twin Hollows extends from the foot of Carroll's Island to the head of Beard's Island (Plate I), a distance of about $3\frac{1}{2}$ miles. It is immediately below and adjoining Horsetail. Issuing from the foot of Carroll's Island, with a width well adapted to good navigation, the stream gradually widens out, until just above Beard's Island it has a width of 6,350 feet between banks. This great width has the same result here that it has elsewhere, viz, great deposits in the bed during high water and feeble scouring power as the water falls, the consequence often being a badly obstructed navigation during the low stages of the autumn. These deposits being irregular in shape and movable, the obstructions are not always found in the same place, and they do not always exist in the same degree. They have sometimes been found opposite Twin Hollows, and sometimes opposite the head of Beard's Island. At either or both of these places the channel depth is liable to be as little as 4 feet, and if deep water happens to exist at these particular points, the shoals are liable to be found somewhere between them. It sometimes happens that from the peculiar form of the deposits, or the lightness of the material, or a natural concentration of the water, or other causes, the scouring power is sufficient to cut out the deposits in the channel before the stage of water has fallen so low as to make them obstructions to navigation. In the autumn of 1879 a channel depth of but 4 feet 4 inches was found opposite the head of Beard's Island, the river being at a stage 3.8 feet above standard low water, while in 1880 no obstruction was met with, and in 1881 the least depth was $6\frac{1}{2}$ feet, the river being at a stage 4.75 feet above standard low water. It promises to be as bad this year as it was in 1879, if not worse.

The plan adopted for the improvement was simply a continuation of the general plan for the improvement of the navigation between Saint Louis and Cairo, viz, to contract the river to an approximately uniform width of about 2,500 feet, and to protect the alluvial bank from erosion. In deciding which of the present banks was to be retained and which was to be built out there were no complications of local interest. There was no regular steamboat landing upon either bank. The question was narrowed down to one of cost and of convenient use of the river for navigation during the execution of the works. The rocky bluff of the Missouri shore constitutes a bank that it is certainly very desirable to retain, and

if circumstances could justify the expectation that the opposite bank could be pushed out without much greater effort than in the case of the Missouri bank, there would have been little difficulty in deciding. Unfortunately, the circumstances were opposed to such an expectation. The channel was found on the Illinois side, or near it, all the way from Carroll's Island to the foot of Beard's Island (see Plate VI), a distance of over 4 miles. In no case throughout this distance did it approach the Missouri shore to a distance less than 2,500 feet, and for a considerable portion of the length it was over 3,500 feet distant. The space between the channel and the Missouri shore was largely occupied by sand-bars, which were dry at a stage 5 feet above standard low water. The waterway between them and the Missouri shore was in many places insignificant at a 5-foot stage, and entirely obliterated at low water. If the Missouri shore had been retained it would have been necessary to excavate a practically new bed for the river and to fill up the greater part of the present bed. This could have been done, but it would have been a difficult and costly undertaking, and it could not have failed to cause great annoyance to those engaged in navigating the river. A much easier and simpler plan was to build out where it was shoal, preserving the deep water where it was. This plan was adopted with the less hesitation when to the foregoing was added the consideration that no attempt should be made to hold the river against the bluff all the way to Sainte Genevieve. To do so would be to shorten the river several miles, greatly magnifying the difficulties and expense of the whole work, increasing the slope and obstructing ascending navigation. To push the river in against the bluff at Twin Hollows would probably push it away from the bluff below and spoil the present favorable condition of affairs between Kimmswick and Rushtower, where for 15 miles the channel closely follows the bluff.

It was therefore decided to hold the present Illinois bank as far down as the point I (Plate VI), using a revetment where it was needed to build up a new bank on the line I K to the head of Beard's Island, and to revet the west side of that island. Using the line thus constructed as a directrix, the Missouri shore was to be built out to an approximate distance of 2,500 feet from it.

For convenience in administration the works on the different sides of the river were placed under separate organizations. That on the west side was begun in September, and was continued, under many difficulties (see Appendixes A and D), until the close of the fiscal year, except during the winter months. The works as they were at the end of the year are shown on Plate VI. The primary hurdle had been partially constructed for a length of about 8,800 feet from its upstream end, of which about 5,000 feet had been completed. Four secondary hurdles had been nearly completed. Owing to the rocky nature of the bed near the Missouri shore, into which piles could not be driven, it was necessary to devise special forms of construction (Plates VIII and IX) to meet the case. The resulting delay in connecting the lines with the shore was a serious drawback. Nevertheless, large deposits have been secured within the area to be reclaimed. The works have not progressed far enough to exert any effect upon the channel.

The heavy caving of the Illinois bank below Carroll's Island, combined with the prolonged high water of last autumn, threw a vast quantity of solid material into the channel, and finally this spring forced it out of the location which it had occupied, opposite Pull-tight, and caused it to cross over to the Missouri shore, as shown on Plate VI.

This change will render it undesirable to push the work at Twin Hol

lows as rapidly as was at first intended. The channel now occupies ground which it is intended to reclaim, and the encroachments upon it must be slow and gradual. The caving above has been stopped by the work on the east bank, the crossing has worked downstream fully one-half a mile in the last two months, and it is thought that the channel can be brought back to its former position without great effort.

In order, however, to avoid obstructing navigation, the work must progress slowly.

The expenditures at Twin Hollows, west bank, were \$103,500.25.

TWIN HOLLOWES, EAST BANK.

The Illinois bank, below Carroll's Island, which had been comparatively stationary for a number of years, began caving with great rapidity in the summer and autumn of 1881.

Before this could be stopped a strip of land about 8,400 feet long and varying in width from 50 to 300 feet was destroyed. The channel crossing from the Missouri shore struck the bank at an obtuse angle, presenting the case where a wide and deep protection was required. The width of the mattress to be placed below low water mark was fixed at 120 feet.

The work was begun in October, and was still in progress at the end of the fiscal year. At that time three mattresses had been placed below low water mark, as shown on Plate XI, one 1,493 feet long, one 3,800 feet long, and one 1,325 feet long. A fourth mattress was under construction, and had reached a length of 964 feet, but no portion of it had been sunk. The 6,618 linear feet of mattress placed covered 5,925 linear feet of the bank, the difference being due to the overlap of contiguous mattresses. The downstream end of the second mattress was so badly damaged in sinking that it was necessary to overlap it several hundred feet. The extension of the protection up the face of the bank was not made continuous. The upper part of the bank was usually vertical where the low water mattress was placed. The latter immediately stopped the undermining, and the further erosive action of the river helped the work by grading the upper part of the bank to a gentle slope. This action was carefully watched, and whenever the grading was completed to the desired slope riprap was deposited upon the bank above low water, thus completing the protection. A total length of 2,350 feet was thus completed. For details of this work and the difficulties encountered see Appendixes A and F.

The bank was for the greater part of its length covered with large trees, which, after falling into the water, constituted obstructions in the way of laying the mattress which it was necessary to remove. The snag-boat General Barnard, with crew, was temporarily transferred to me for this purpose by Major Mackenzie under the authority of the department. She was engaged for several weeks in September and October, her expenses being paid out of the appropriation for the work. These, amounting to \$1,663.40, are included in the statement of expenditures below. She removed one hundred and thirty-five snags from the water, and her crew cut down two hundred and ninety-six trees which were standing, but were about to become snags as the caving progressed. Work of this character was again required in the spring. The snag-boat Wright, being engaged in the vicinity in removing snags from the channel, removed also these obstructions, under orders from Maj. Charles R. Sater, Corps of Engineers, to whom I am indebted for that assist-

ance. There was no expense to the appropriation for the work for the services of the *Wright*.

To complete the work there remained to be placed about 2,500 feet of low water mattress, of which 964 feet was already fabricated, and deposit riprap upon a length of about 6,075 feet of the bank. Hurdles to close the small chute below Pull-tight will also be required. It is expected to accomplish this during the present working season.

The expenditures were \$72,696.63.

BEARD'S ISLAND.

The protection of the west side of Beard's Island and the closure of the small chute north of the island constituted a part of my project of January 28, 1881, for the improvement of the river between Carroll's Island and the mouth of the Meramec. The bank was caving at that time, and it continued to do so until it was stopped by the work of this year, a strip of land about 7,500 feet long and in many places 800 feet wide having been destroyed since October, 1880.

The case presented for the bank protection was similar to that at Carroll's Island and Twin Hollows, east bank, and the same width of mattress, 120 feet, to be placed below low water mark, was adopted. The work was begun about the end of March, and was in progress at the end of the fiscal year.

Three mattresses 120 feet wide were placed as shown on Plate XII, one 3,250 feet long, one 360 feet long in prolongation of the first, and one 300 feet long, used to cover a break in the first mattress which occurred in sinking. A fourth mattress was under construction at the end of the year, and had reached a length of 550 feet, but no portion of it had been sunk. The length of bank which received the low water protection was 3,550 feet. The protection was extended up the face of the bank by a layer of riprap after it was graded to a gentle slope by the erosive action of the river. The length so completed was 1,650 feet.

A hurdle about 1,000 feet long was built in May and June across the small chute north of the island. It was not finally completed until the end of June, although it caused heavy shoaling before it was finished. The river was at flood a few days afterwards. When the water fell to a 28-foot stage it left the chute dry, a vertical fill of over 40 feet having occurred within a few weeks. Considering the high level of the top of this deposit and the short length of time required to secure it, this is the most remarkable result yet accomplished by hurdles on the Mississippi. For details of the work see Appendixes A and G.

There remained to complete the work the placing of about 3,950 linear feet of mattress and the placing of riprap upon the bank above low water for a length of 5,850 feet. It is expected that this can be accomplished during the present working season.

The expenditures at Beard's Island were \$35,614.53.

"JIM SMITH'S."

The eighth and ninth shoals below the Saint Louis Bridge are found in the reach just below Beard's Island, and extending to Kimmswick, a distance of about $3\frac{1}{2}$ miles, known to steamboat men as "Jim Smith's." (See Plate I.) The conditions here are similar to those above described for Twin Hollows, except that in this case there is a regular steamboat landing on each side of the river, Kimmswick on the west side and Smith's Landing on the east. The width between banks varied from about 4,000 to about 7,000 feet. The least channel depth found in 1879

was 6 feet; in 1880, 7 feet; and in 1881, 6½ feet; the stage of the river in all cases being more than 4 feet above standard low water.

A project for the improvement of the locality was forwarded to the department with my letter of September 12, 1881, and was approved by department letter of November 2, 1881. The plan was in general the same as that for other localities, viz, to reduce the width of the river to about 2,500 feet. The selection of the lines for the new banks was controlled by the following considerations, viz: 1st. The location of the channel was for the greater part of the distance on the west side of the river, and thus favored building out the east bank. 2d. To build out the east bank, while preserving the natural length of the river, would bring it smoothly against the rocky bluff at Kimmswick. 3d. The Kimmswick Landing is of more importance than Smith's Landing, on the opposite side, the former being a flourishing town of about 800 inhabitants, while at the latter there are but a few scattered farm-houses, the landing itself being located upon an alluvial bank, subject to erosion. It was necessary to interfere with one landing or the other, and the latter was selected. It was accordingly decided to take as the new right bank the east side of Chesley Island, as far down as about its middle, from which point the direction is to be a straight line tangent to the rocky point at Kimmswick. (See Plate I.) The new left bank is laid out parallel with it and 2,500 feet distant. The chutes between Chesley Island and the Missouri shore are to be closed at the lower ends, the upper ends being left open to provide an exit for the Meramec River, and also a catchment basin for the gravel brought down by that stream.

The steamboat landing at Smith's is thus temporarily cut off from navigable water until the works shall have accomplished their object of building up the new bank. This will occasion some inconvenience to the people of that neighborhood for one or two seasons, but will finally result in giving them a more secure landing than the present one, which is often difficult of access. In cases of this kind, which will no doubt occur frequently as the improvement advances, it is proposed to place the piles so that a pier can be constructed upon them by those who require access to navigable water.

It was determined to begin this work when it had become evident that the work at Twin Hollows, west bank, could not be pushed to completion this season. It was begun in the latter part of May, at the point F, Plate VI, on the Illinois side. The initial point was made here instead of at the foot of Beard's Island, for the reason that the distance from the point F was less than from F to the island, and it is expected that the space below the island will be filled up without further work when the hurdles below Pull-tight shall have finally closed the east chute. The direction of the line F F, oblique to the shore, is given to facilitate construction by favoring the removal of drift-wood. When the work was begun it was expected that the high water, which had lasted with slight intermission for nearly a year, was about to come to an end. This proved not to be the case, and the work was much obstructed until the end of the year. At that time the primary hurdle had been constructed for a length of about 1,000 feet. Although the cost of the work was great, its results were prompt and large, heavy shoaling having been caused within the area to be reclaimed. Special forms of construction were used to meet the difficulties occasioned by high water. They are shown on Plate XIII, and are described in Appendixes A and H. The work has not advanced far enough to exert any effect upon the channel.

The expenditures were \$11,068.37.

DIOKEY'S ISLAND TO THE MOUTH OF THE OHIO.

No work was done upon the protection in rear of Cairo, and it is here mentioned merely as an illustration of the inutility, so far as the navigation interest is concerned, of working at detached points upon the river. The bend in which the caving bank was protected has now been deserted by the channel and is rapidly filling up, the greater part of it being dry at a 20-foot stage. The work done there, however valuable it may have been to the city of Cairo, has been of no permanent value to the navigation interest. The amount expended there, \$119,868.66, must now be added to the estimate for improving the navigation between the mouths of the Illinois and Ohio rivers.

CONTRACTION WORKS.

The works at Horsetail, Twin Hollows, and "Jim Smith's" have been of the same general character as those used in former years at Horsetail, viz, a well-braced hurdle, built upon the line of the proposed new bank, called a primary hurdle, and connected at intervals with the shore by hurdles called secondary hurdles, built upon lines perpendicular to the primary hurdles. The principal modification in their use has been to increase the strength and diminish the number of the secondary hurdles. Greater strength was found necessary to enable them to resist the heavy masses of drift-wood which are liable to accumulate against them at every rise. It has been attained by thorough bracing and a foundation mattress of brush. This added strength has rendered less necessary their mutual re-enforcement, and the interval between them has accordingly been increased to 2,000 feet.

The height to which they are built, where there is any choice in the matter, has also been modified. The height at first adopted was 15 feet above low water of 1863, the reasons for fixing upon that height being that above that level willows would grow, and would prove a more durable silt-catching arrangement than the hurdles. These reasons still exist, but the necessity of extending the working season over periods when the river is at a higher stage has made a modification necessary. While a hurdle is in process of construction it is necessary that it should be visible; that is, that its top should project above the water surface. The higher the stage, the higher must the hurdle be built. To carry it just to the water surface and then stop would cause great irregularity in the heights. This is objectionable for the reason that if one hurdle projects very much above the others it will be subjected to unusual strains from drift-wood at times when the others are submerged. Absolute uniformity in height is not attainable without fixing as the standard the highest stage at which the work may be carried on. The advantage to be gained by this would not compensate for the great additional expense. A reasonable uniformity in ordinary years can be attained by fixing the height at 16 feet above standard low-water, and that is the height which has been adopted.

BANK PROTECTION.

The solution of the problem of protecting alluvial banks from caving and erosion must differ according to different circumstances. It is evident that where the main channel flows parallel to the bank, as in a narrow and straight part of the river, the circumstances are entirely different from those where it crosses from one side of the river to another and strikes the bank at a very obtuse angle. In the former case there

will be a gradual wear of the bank, which will extend down to but a moderate depth, resulting from the friction of the water against the light, uncompressed soil. In the latter case the bank lies in the path of the channel instead of at one side of it, and has, in addition to the friction, to resist a series of blows as from a jet; the deepest water is found near the shore, the bank is rapidly undermined, and heavy caving results. These circumstances are usually found in a concave bend. It is evident that in this case the protection must extend down to a much greater depth than in the former.

In both cases a permanent protection can be most economically obtained by dividing the bank into three zones, which are nearly horizontal, the lower zone extending from the lowest limit of erosion up to low water mark, the middle zone from low water mark up to the level at which a live growth of willows will flourish, and the upper zone extending from the latter level to the top of the bank. The lower zone, being always covered with water, may be permanently protected by a brush mattress. In the second or middle zone, which is subjected to constant alternations of wetting and drying, due to the oscillations of the river, a protection of brush must necessarily have but a brief life; in this zone a layer of riprap is required. In the upper zone a live growth of willows will form an efficient and permanent protection. To prepare the bank to receive the protection, it is graded to a gentle slope.

The difference in the method of construction adopted in the two cases lies entirely in the construction of the mattress to be placed below low water mark. In the first case a width of 35 or 40 feet is sufficient, and as the current near the shore is usually moderate, like the depth, no great difficulties are presented. Such a case was found at Arsenal Island. The method adopted is described in Appendixes A and B. In the second case the width of the mattress must be much greater, and as the depth and velocity of the water are greater, the difficulties of placing the mattress in proper position so as to give a continuous covering to the bank are much increased. To insure continuity, but few mattresses, and these of great length, must be provided. The design prepared to meet the general requirements of this case is shown on Plate XIV. A depth often found in a caving bend is 40 feet at low water. Allowing the slope of the bank below the water surface to be 1 on $2\frac{1}{2}$, the distance from low water mark to the bottom of the river, measured on the slope, is about 110 feet. A mattress of that width would be sufficient to cover the slope if its upper edge could be placed exactly on the low water line. Practically that is impossible. The edge of the mattress must be in plan a smooth line, with easy changes of direction, while the low water line is usually very irregular in direction. The upper edge of the mattress, when placed, will, in some cases, fall below the low water line, and in some cases above it. To provide for these irregularities and insure reaching the foot of the bank at all points, a slight additional width is required. The width of the mattress is fixed at 120 feet, its length to be as great as practicable. It is fabricated upon floating ways prepared for the purpose, having their slope up and down stream. The mattress is launched progressively as it is constructed, the ways being pulled out from beneath it and moved a short distance downstream, retaining the downstream end of the mattress, but leaving the balance of it floating upon the water. It is securely fastened to the line of guide-piles near the shore. By this method the only limit to the length of the mattress that may be constructed, if the difficulty of sinking be left out of account, is the length of the working season.

Where the depth and velocity are not excessive, it is possible to sink the upstream portion, leaving the downstream portion still upon the

surface of the water, and thus by progressive sinking to place in position on the bank a mattress of very great length. Mattresses 3,800 feet long and 3,250 feet long, respectively, were placed this spring at Twin Hollows, east bank, and Beard's Island, the downstream end of the first, however, in a damaged condition. This exposes a portion of the mattress to heavy strains from the current, and in many cases these will be great enough during the higher stages of the river to wreck its downstream end. In such cases the length is limited to the amount that it is possible to sink in a single operation. In the original design this limit was fixed at 1,000 feet, but in practice it has been exceeded. One mattress 1,325 feet long, and another 1,500 feet long, completed after the close of the fiscal year, have been successfully sunk in a single operation at Twin Hollows, east bank.

The method has been subjected to as severe tests, both as to difficult circumstances of execution and as to subsequent efficiency, as it will probably ever receive, and it has proved highly satisfactory.

METHOD OF CARRYING ON THE WORK.

All work during the year has been done by hired labor and purchase of material in open market. It is proposed to continue the system during the coming year, for the reason that the character of the work will not admit of the contract system without injury to the interests of the United States. The reasons for this were fully set forth in my annual report for 1880. (See Annual Report of Chief of Engineers for 1880, pages 1374, 1375.)

EQUIPMENT.

The principal additions to the equipment during the year were the completion of the fourteen steam pile-drivers begun last year, the construction of two sets of floating ways for bank protection, thirty-seven portable buildings for quarters, eighty small flats, and one hydraulic excavator, and the purchase of two second-hand coal-barges, forty-two yawls, and eighty-two skiffs. The equipment is now adapted to the scale of operations provided for in the river and harbor act of March 3, 1881, that is, for an expenditure of \$600,000 per year. A special record is kept, in which it is treated as so much unexpended appropriation, each work being charged for the use and repair of such as may be employed upon it.

The present valuation of the property remaining to be distributed in the future is given in the last column of the following table, in which are given also its valuation at the beginning of the year, the sums which have been expended upon it, and its estimated deterioration during the year:

Class of property.	Balance July 1, 1881.	Dr.	Cr.	Balance June 30, 1882.
Steamer A. A. Humphreys	\$18,814 17	\$4,408 52	\$2,123 53	\$21,199 16
Steamer Anita	4,831 97	809 00	2,751 41	2,910 22
Launch Hornet	105 71	286 92	286 07	106 56
Tug Mignon	4,077 72			4,077 72
Barges	71,320 17	37,038 44	25,851 24	82,507 37
Pile-drivers	33,176 55	29,401 08	7,217 40	55,420 81
Quarter-boats, quarters, shops, &c.	15,445 05	31,004 92	5,740 51	41,689 46
Skiffs, flats, &c.	1,764 98	14,119 88	2,854 29	13,030 57
Tools and appliances	4,411 82	7,014 01	4,185 43	7,241 00
Hydraulic excavator		8,538 31	1,079 08	7,458 33
Ways for mattresses		6,401 17	750 08	5,711 09
Office furniture	441 95	592 25	120 81	913 36
Surveying instruments, &c.	1,114 95	636 91		1,751 86
Boarding outfit		12,501 14	142 19	12,358 95
Totals	155,625 04	153,864 41	53,102 97	256,366 45

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The hydraulic excavator consists simply of a powerful steam pump (see Appendix I), placed upon a scow and furnished with the necessary boiler power and hose for throwing powerful jets of water, its principal object being to grade the banks for receiving a revetment. The boiler is 20 feet long, 42 inches diameter, with two 14-inch flues, and has a nominal 25-horse power. The pump provides two jets, thrown from 2-inch nozzles, the water being conducted from the pump to the desired point through flexible $4\frac{1}{2}$ -inch 6-ply hose. The nozzle used and the arrangement devised for guiding the stream are shown on Plate XV. With this arrangement the stream can be guided by one man.

The steamer Humphreys was provided with an electric light, enabling her to work nearly as well by night as by day.

The expenditures upon additions to equipment were \$140,134.11.

TELEPHONE LINE.

Telephonic communication between the field offices, the supply depot, and the Saint Louis office having become necessary to the economical prosecution of the works, an arrangement was entered into with the Bell Telephone Company of Missouri, by which they erected a private telephone line on the west side of the river, and engaged to keep it in repair, furnishing all the necessary instruments and apparatus. The line was at first constructed as far as Twin Hollows, and was afterwards extended to the mouth of the Meramec, when the work was begun at "Jim Smith's." Telephone instruments were placed in the offices at 404 Market street, at the supply depot, at Horsetail, at Twin Hollows, and at the mouth of the Meramec. They have been in daily use, and have prevented the necessity of providing an additional tow-boat for supplying the works. The line has also been the means of avoiding innumerable delays in the procurement of supplies, and has brought the works under the close supervision of the main office. The price agreed upon for this service was, for the line from 404 Market street to Twin Hollows, \$2,050 for the first year, and \$1,055 for each succeeding year, and for the extension to the mouth of the Meramec, \$1,190 for the first year and \$130 for each succeeding year, or for the entire line \$3,140 for the first year and \$1,485 for each succeeding year.

SURVEYS.

The general topographical survey, which at the beginning of the year had reached Allen's Landing, 83 $\frac{1}{2}$ miles below Saint Louis, was resumed in July, and was carried through to Cairo, a distance of 106 miles, before winter, and was thus completed. Two parties were engaged, under the respective direction of Mr. W. S. Mitchell and Mr. John O. Holman. The plane-table sheets were finished in the office during the winter. There is now a series of correct maps, scale $\frac{1}{100,000}$, based upon the triangulation of 1874, covering the Mississippi from the Illinois to the Ohio. They constitute a valuable historical record.

The gauges at Grafton, Alton, and Gray's Point were read daily. Their records are appended, marked K, L, and M, respectively. The record of the Gray's Point gauge from August 29 to September 13 is omitted, for the reason that the lower section of the gauge had been disturbed, and it had not been possible to ascertain its error on account of high water.

The expenditures upon surveys and gauge readings were \$9,217.17.

NAVIGABLE DEPTH BETWEEN SAINT LOUIS AND CAIRO.

The reports made to the association of Saint Louis and New Orleans pilots by its members have been transferred to me, as last year, and from them has been made a record of the depths found upon the bars between Saint Louis and Cairo throughout the year. So much of it as covers the low water season is herewith transmitted, marked N. As explained in my last annual report, strict accuracy is not claimed for any one measurement. The record, to be of value, should be taken as a whole, several days' measurements, and the gauge records being considered together. The only low water period that occurred during the fiscal year was in parts of the months of August, September, and February, the lowest stage reached being 4.6 feet above standard low water. The least depth reported was 5 feet, and was found at Cairo Point. A depth of 5½ feet was found at Jones's Point and at Eliza Point. Upon all other bars a greater depth was found.

MISSISSIPPI RIVER COMMISSION.

The Mississippi River Commission having expressed a desire to make a formal examination of my works and plans, I was directed by the department to give them all desired information, and in a conference of several days last October I did so. In their report to the honorable Secretary of War, of November 25, 1881, they fully indorsed the plans and the methods of carrying them out. Indeed, in all the discussions which have agitated and confused the public mind upon the subject of plans for improving the navigation of the Mississippi, no professional engineer has, so far as I know, ventured to question the correctness of the plans adopted by the Engineer Department, and in process of execution at the time the Commission was organized.

ESTIMATE FOR YEAR ENDING JUNE 30, 1884.

Although the appropriation bill for the year ending June 30, 1883, had not become a law at the end of the year, the present estimate is submitted with a knowledge of its provisions. The amount which can be profitably expended during the year ending June 30, 1884, is \$1,000,000.

It is proposed to expend it in carrying out the programme described in my last annual report. This is to make the improvement continuous, working down stream from Saint Louis, by reclaiming land and building up new banks, thus reducing the river to the approximately uniform width of about 2,500 feet. It is proposed by this means to secure a minimum depth of 8 feet. The depth is now liable to become as little as 4 feet in some places, and less than 8 feet in every place where the width is greater than 2,500 feet. Alluvial banks are to be protected from erosion. This general statement of the proposed application of the appropriation is as specific as the nature of the case will admit of. The changeable character of the river renders it impracticable to give in advance the exact localities where works will be required.

The work is located in the collection district of New Orleans.

Amount of revenue collected at the port of Saint Louis for the fiscal year ending June 30, 1882, was \$1,676,951.56.

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Money statement.

July 1, 1881, amount available.....	\$616,809 35
July 1, 1882, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1881.....	\$466,168 88
July 1, 1882, outstanding liabilities.....	38,495 29
	<u>504,664 17</u>
July 1, 1882, amount available.....	112,145 18
Amount appropriated by act passed August 2, 1882.....	600,000 00
	<u>712,145 18</u>
Amount available for fiscal year ending June 30, 1883.....	712,145 18
Amount (estimated) required for completion of existing project.....	*5,094,288 98
Amount that can be profitably expended in fiscal year ending June 30, 1884.	1,000,000 00

Construction account.

Name of work.	Expended prior to July 1, 1881.	Expended during fiscal year end- ing June 30, 1882.	Total cost to June 30, 1882.
Piase Island Dam.....	\$32,333 30		\$32,333 30
Alton Dam.....	33,623 92		33,623 92
Sawyer Bend protection.....	96,803 63		96,803 63
Venice Dikes.....	36,341 85		36,341 85
Armed Island protection.....	9,673 85	\$14,513 88	24,187 73
Closing Cahokia chute.....	116,088 00		116,088 00
Horsetail Bar, Dike 1.....	40,549 53		40,549 53
Horsetail Bar, Dike 2.....	23,600 26		23,600 26
Horsetail Bar, Dike 3.....	82,692 54		82,692 54
Horsetail Bar, Dike 4.....	41,200 11		41,200 11
Horsetail Bar, Dike 5.....	36,933 87		36,933 87
Horsetail Bar, training wall.....	80,627 03		80,627 03
Horsetail Bar, primary hurdles, secondary hurdles.....	205,836 10	98,563 23	304,399 33
Twin Hollows, west bank, primary hurdles.....		103,500 25	103,500 25
Twin Hollows, west bank, secondary hurdles.....			
Twin Hollows, east bank, mattress.....		72,696 63	72,696 63
Twin Hollows, east bank, revetment.....			
Beard's Island, primary hurdles.....			
Beard's Island, mattress.....		35,614 53	35,614 53
Beard's Island, revetment.....			
Jim Smith's, primary hurdles.....		11,068 37	11,068 37
Jim Smith's, secondary hurdles.....			
Fort Chartres Dam.....	36,812 86		36,812 86
Turkey Island.....	24,463 85		24,463 85
Kaskaskia protection.....	66,465 62		66,465 62
Liberty Island Dam.....	5,053 01		5,053 01
Liberty Island protection.....	45,129 40		45,129 40
Devil's Island, Dike 1.....	65,871 17		65,871 17
Devil's Island, Dam 1.....	49,848 58		49,848 58
Devil's Island, Dam 2.....	16,678 30		16,678 30
Calro protection.....	110,868 66		110,868 66
Alton Dike.....		33,324 70	33,324 70
Minton Point, primary hurdles.....		33,436 37	33,436 37
Minton Point, secondary hurdles.....			
Cape Girardeau, primary hurdles.....		10,093 59	10,093 59
Total.....	1,206,586 94	412,801 55	1,679,388 49

* NOTE.—Estimate of last year increased by amount previously expended between Dickey's Island and mouth of Ohio, and by amount allotted to Alton Harbor by act of August 2, 1882.

Property and material account.

Class of property.	Balance July 1, 1881.	Total debits.	Total credits.	Balance June 30, 1882.
Steamer Humphrey and expenses	\$18,914 77	\$29,554 80	\$27,270 41	\$21,199 16
Steamer Anita and expenses	4,851 97	10,613 88	12,555 63	2,910 23
Launch Hornet and expenses	105 71	1,587 31	1,586 46	106 56
Tug Mignon and expenses	4,077 72	1,049 40	1,049 40	4,077 72
Steamer Little Eagle, No. 2		7,707 84	7,707 84	
Barges	71,320 17	45,952 12	34,704 92	82,507 37
Pile-drivers	33,176 55	43,360 69	21,116 41	55,420 83
Quarters, shops, &c.	15,445 05	32,702 48	13,974 05	32,173 48
Quarter-boats		9,849 49	2,323 51	7,525 98
Skiffs, &c.	1,704 98	14,248 74	2,983 15	13,030 57
Tools and appliances	4,411 82	21,169 91	18,340 73	7,241 00
Hydraulic excavator		8,538 31	1,079 98	7,458 33
Ways for mattresses		0,961 17	1,250 08	5,711 09
Office furniture	441 95	592 25	120 84	918 36
Surveying instruments	1,114 95	636 91		1,751 86
Material, stone, Little Rock	1,581 99			1,581 99
Material, stone, Saint Louis		24,832 08	24,807 30	524 78
Material, piles, Saint Louis		84,726 30	78,186 64	7,711 34
Material, brush, Saint Louis	1,121 68	65,815 65	62,103 59	3,929 26
Material, stone, Minton Point	217 20	2,634 97	1,845 42	789 55
Material, piles, Minton Point		13,536 90	11,402 85	2,134 55
Material, brush, Minton Point		4,347 42	3,691 47	755 95
Material, miscellaneous	3,053 70	36,518 72	28,069 00	11,503 42
Subsistence		37,608 30	32,907 28	4,701 02
Boarding outfit		12,501 14	142 19	12,358 95
Total	161,000 21	517,046 78	388,628 65	290,018 84

A.

REPORT OF MR. D. M. CURRIE, ASSISTANT ENGINEER.

SAINT LOUIS, MO., August 4, 1882.

SIR: I have the honor respectfully to submit my annual report upon works of which I have had supervision, under your direction, during the fiscal year ending June 30, 1882; and to transmit the annual reports by assistants charged with the duties of supervising construction at each of the localities at which works were constructed, each assistant reporting upon works at the locality at which he was stationed at the close of the year. They are:

1. Arsenal Island, by Mr. A. F. Freis, assistant engineer.
2. Horsetail Bar, by Mr. A. F. Freis, assistant engineer.
3. Twin Hollows, west side, by Mr. W. S. Mitchell, assistant engineer.
4. Carroll's Island, by Mr. C. V. Mersereau, assistant engineer.
5. Twin Hollows, east side, by Mr. C. V. Mersereau, assistant engineer.
6. Beard's Island, by Mr. J. W. Record, assistant engineer.
7. Jim Smith's, by Mr. John O. Holman, assistant engineer.
8. Engineer Depot, by Mr. C. L. Stevenson.

The report of each assistant being submitted upon the works at the locality at which he was charged with the duty of supervising construction at the close of the year, does not of itself indicate the connection that he had with the work. None of them were connected with these works prior to the 28th of last February, upon which day your order was issued making assignments of assistant engineers, as follows: Mr. W. S. Mitchell to be assistant engineer at Twin Hollows, west side; Mr. J. O. Holman to be assistant engineer at Twin Hollows, east side; Mr. J. W. Record to be assistant engineer at Beard's Island; Mr. A. F. Freis to be assistant engineer at Horsetail Bar, and Mr. C. V. Mersereau to be assistant engineer at Arsenal Island and Engineer Depot.

The following changes were made by your orders, dated May 4: Mr. C. V. Mersereau to Twin Hollows, east side; Mr. J. O. Holman to Jim Smith's, and Mr. A. F. Freis to Arsenal Island, in addition to the duties at Horsetail Bar; and on the same day Mr. C. L. Stevenson was assigned to duty as clerk, charged with the supervision of construction at the Engineer Depot.

Further reference will be made to each of these reports under the head of the locality of which it treats.

Each of the gentlemen whose reports are herewith transmitted are entitled to credit for faithful performance of duty and zealous devotion to his work.

I. ARSENAL ISLAND.

This work had for its object the maintenance of the normal width of the river, by preventing the erosion of the west bank of the island farther to the eastward than the line selected for the proposed east shore, and was begun in 1877, when a short section near the upper end was protected by a revetment of stone placed upon the bank after it was graded to a suitable slope to receive it. Upon this section the revetment extended up to the top of the bank.

The extension of the revetment down stream was delayed until the fall of 1879, while waiting for the erosion to proceed far enough to cut the proposed line of the east bank of the river.

This line having been reached upon a section of bank extending about 3,500 feet farther down stream, the revetment was extended to that distance, but only to a height of about 12 feet above extreme low-water, and was laid upon the slope of the bank graded only by the action of the current, but that was suitable for retaining stone, about two horizontal upon one perpendicular being the general inclination below the mean stage. The bank above that plane was not protected immediately because grading was necessary to prepare it to retain stone placed in revetment, and this work could be done by the current during higher stages of the river cheaper than by any other available means, the character of the bank being such that it could be safely left to be graded by such action. This grading and the erosion of the bank in front of the proposed shore line on the lower part of the island having been completed during the flood of the summer of 1891, the work of raising the revetment and extending the protection to the foot of the island was begun about the 1st of November, was suspended on the 17th of the same month, resumed on the 6th of March, and continued uninterruptedly until the close of the year.

The revetment begun in 1879 was completed by raising it to 16 feet above the plane of standard low water; the protection below that plane was extended down stream by placing 2,450 linear feet of mattress located as shown upon the map of the island, Plate II. This mattress has not been connected with the stone-work above, and a breach occurs in its continuity. The space between its upper end and the old work was left to await the result of hurdles built to re-establish the line of bank which had been cut away by an eddy started by a sunken barge lodging near shore opposite that point soon after the revetment of 1879 was constructed. The hurdles are rapidly accomplishing that object, leaving but little doubt that the new bank will be ready for protection during the next low water season.

The gap in the mattress was made by the loss of a section while under process of construction during the flood-stage at the close of the year. This will probably be replaced, the mattress extended to the foot of the island, and the revetment completed during the approaching season of low water.

In the protection of this island two forms of construction have been used; the first applied to that part of the protection which was begun prior to this year, and the second to new work. The first shown in cross-section in Fig. 1, Plate II, consists of a revetment of stone placed upon the surface below the plane of 16 feet above standard of low-water and of willows planted upon the slope above that plane. The second, shown in Fig. 2, Plate II, differs from this only in having a mattress of sufficient width to cover the slope between the plane of standard low-water and the bottom of the river, the slope above being treated in the same manner as in the first method.

The mattress used was about 40 feet wide with the tops of brush in the course normal to the current, extending about 10 feet farther into the stream. It was built in place and supported by lashing the grillage poles to the guide piles upon one side and by resting them upon small flats upon the other. It may be constructed in any desired lengths provided that the stages of the river should be favorable. The sections built have varied between 450 and 724 feet, although the river was high during nearly the entire time that the work was in progress, about equal to that of the tops of the guide piles, and frequently it ran full of drift-wood.

Reference is made to the accompanying report of Mr. A. F. Freis, assistant engineer, for further history of the works and quantities of material consumed therein.

The expenditures aggregate \$14,513.88, distributed as shown in the following statement:

Material:

Brush, secondary hurdles	\$189 00
Piling, secondary hurdles	463 45
Labor, secondary hurdles	222 55
Equipment, secondary hurdles	191 46
	<hr/> \$1,066 46

Material:		
Brush, mattress.....	\$2,336 72	
— Stone, mattress.....	790 47	
Piling, mattress.....	660 92	
Miscellaneous, mattress.....	429 89	
Labor.....	2,305 70	
Equipment.....	508 39	
		\$7,032 09
Material, stone, revetment.....	4,894 15	
Labor.....	845 73	
		5,739 88
Engineering and contingencies.....		675 45
		<u>14,513 88</u>

II. HORSETAIL BAR.

Operations at this locality were in progress at the beginning of the year, and were continued until the close with such interruptions only as were made necessary by unfavorable weather and stages of water.

The interruptions from these causes, however, were considerable. On account of the high stages of water only a small force could be economically employed during the first half of July, from the 1st of October until the close of the fall season, and during the month of June, while on account of unfavorable weather field-work was suspended from December 6 to March 20.

The year's operations began with a small party of laborers engaged in reconstructing the east primary hurdle line down stream from the point 200 feet below its intersection with secondary line No. 21, where that work was suspended during the preceding spring. When the river reached a stage favorable for enlarged operations, about the middle of July, that party was increased, and other parties were organized to resume work generally, repairing, reconstructing, and extending hurdles, which had been under process of construction, and beginning new lines. From the middle of July until the last of September the work was vigorously prosecuted, using to its full capacity the entire available plant, including barges, pile-drivers, small boats, and quarters; and during that time the east primary line had been completed a distance of 3,100 linear feet to its intersection with secondary line No. 29, and piles had been driven for its extension 1,000 feet farther to No. 30, when work upon it was suspended, about the 1st of October, while the work of repairing and extending secondary lines Nos. 27 and 29, and constructing No. 30, was continued until the 1st of November, when these lines had been completed, and were in good condition, with the exception that the large masses of drift-wood which had accumulated behind them had broken a small gap in each of the old channels near the primary line.

On account of the excessive depths due to the high stage of water, further work on these lines could not be economically done; and, therefore, the force was transferred to secondary line No. 18 to repair damages caused by the flood of the early summer, where it worked until the 6th of December.

Of secondary hurdles 4,984 linear feet were built; 1,111 feet were in line No. 18, 1,215 feet in line No. 27, 625 feet in line No. 29, and 2,033 feet in line No. 30.

On the west side the work of constructing the secondary lines which were left incomplete at the close of last year was resumed on the 11th, and that of the primary line was begun about the middle of July, and was continued until the last of September, when 5,390 linear feet of primary hurdles and of secondary hurdles 3,440 feet had been built, of which there were 174 feet in line No. 2, 266 feet in No. 3, 348 feet in No. 4, 509 feet in No. 5, 581 feet in No. 6, 740 feet in No. 7, 750 feet in No. 8, and 72 feet in No. 9.

The length of hurdles on both sides aggregates 8,490 linear feet of primary, of which the area is 164,780 square feet, showing that the average depth was about 19.5 feet, and of secondary hurdles the total length aggregates 8,424 feet, with an area of 177,467 square feet, giving 21 feet average depth.

The work at this point was resumed March 20, and was continued until the close of the year with a force which was increased and decreased as the stage of water became favorable or unfavorable for working.

During the spring season no new work was begun. The gap in secondary line No. 18 was closed, and the repairs of two small breaches which were made by the drift during the flood of June were begun.

The flood of last fall had damaged the primary line to such an extent that in places small channels formed, having sufficient velocity to erode the bed. The damage to the line extended from its head to secondary line No. 24, and consisted in tearing the curtains from the piles, displacing some braces and piles, except at two points, one between secondary lines Nos. 20 and 21, and the other between Nos. 22 and 23, at each of which the piles in both rows were destroyed or torn out of their places, making

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Breaches through which the water passed with such velocity that it removed part of the material deposited during last year.

In repairing, gates were used to replace the destroyed curtains. These were made of plank with spaces between consecutive planks about equal to the width of the plank. In the breaches the bottom was protected by foot-mats extending well to the front of the line and short distances above and below the breach to cover the entire space affected.

The repairs were completed from the head of the line down to a point midway between secondary lines Nos. 21 and 22, and piles were driven in the breach below.

On the west side a portion of the primary line is incomplete. On part of this piles only have been driven. On another part the foot-mat has been placed, leaving only the matting to complete it. The high stage of water kept the piles submerged during the entire working season of the spring, so that this work could not be completed.

The work done during the spring season being added to that of the fall, makes the following totals for the year: of primary hurdles 9,690 linear feet, or 186,320 square feet, showing an average depth of 19 feet, which cost \$5.65 per linear foot, or 29.4 cents per square foot; and secondary hurdles 8,774 linear feet, having an average depth of 21 feet, making the area 184,019 square feet, at cost of \$4.34 per linear foot, or 20.7 cents per square foot.

The expenditures for labor and materials are shown in the following tabulated statement, of which the aggregate is \$98,553.23, distributed as follows:

Material:		
Brush, primary hurdles.....	\$7,939 30	
Stone, primary hurdles.....	3,770 02	
Piling, primary hurdles.....	23,400 10	
Miscellaneous, primary hurdles.....	4,649 83	
Labor, primary hurdles.....	9,288 01	
Equipment, primary hurdles.....	4,765 63	
Subsistence, primary hurdles.....	977 78	
		\$54,791 57
Material:		
Brush, secondary hurdles.....	4,972 55	
Stone, secondary hurdles.....	1,196 79	
Piling, secondary hurdles.....	17,980 92	
Miscellaneous, secondary hurdles.....	2,242 90	
Labor, secondary hurdles.....	7,422 93	
Equipment, secondary hurdles.....	3,885 52	
Subsistence, secondary hurdles.....	404 70	
		38,106 31
Engineering and contingencies.....		5,655 35
		<u>98,553 23</u>

An experiment was made with the use of the water-jet in assisting to open channels through bars, the value of which is not confined to the particular locality.

Upon the approach of the low water stage, about the middle of September, the reef flattened out, lying from Dike No. 1 to the upper end of the Carroll's Island Bar, with nearly equal depth throughout its length, having, however, three slight depressions or channel-crossings, in each of which the depth was about 6 feet when the stage of 8½ feet was reached, which was but little greater than the depth upon its general crest. The upper one of these depressions was selected for the experiment, because its location was at the narrowest point of the bar and within the lines deemed most favorable for the permanent location of the improved channel, considered either in the interest of the navigation or of the permanency of the works.

The jet used was made by uniting the nozzles of the jets upon four pile-drivers to make them discharge, as nearly as practicable, in a single stream; each of these jets was supplied by a Worthington duplex pump with steam cylinders 7½ inches, water cylinders 4½ inches by 10 inches stroke, which could throw about 165 gallons per minute when running at the limit of safety, or with a piston velocity of about 100 feet per minute.

The drivers were firmly lashed together, and by means of three anchors, suitably placed, were drawn back and forth across the reef in the line selected for the channel.

The results were wonderful, the depth having been increased to 8½ feet with sufficient width for the ordinary purposes of navigation within twenty-four hours after the work was begun, and when only 10 hours of actual work had been done. The work was continued one week, at the end of which time 9 feet could be carried over the bar by the largest tows plying upon the river, and the channel became well defined by the line of maximum velocity passing through it.

While the result was valuable as an auxiliary measure in fixing the channel at this

locality, it has a greater value in showing what may be accomplished by means of suitable water jets applied either as auxiliaries to works for permanent improvements, or independently to secure temporary improvement of navigation in advance of the permanent improvement.

Referring to the tracing of the map of this locality (Plate IV), upon which the curves of the stage of 12 feet above low-water at the beginning and close of the year are shown, a decided improvement is found to have been made in the trace of the channel and in the distribution of the deposits made within the inclosed areas on the east side, while upon the west side a large portion of the area to be reclaimed has been raised to the height of the adjoining bank.

The report showing details of construction and expenditure of material is submitted by Mr. A. F. Freis, assistant engineer, to which reference is made.

III.—TWIN HOLLOW, WEST SIDE.

On account of delays experienced in securing suitable persons to board employes, preparations to begin work at this locality were not completed until about the 1st of October, which would otherwise have been done a month earlier. About that time the work at Horsetail Bar had progressed so far that a reduction of the force became necessary, and this was done by transferring a part of it with barges, pile-drivers, and quarters to this locality.

The primary line was located, its construction was begun at the nearest point to its upper end, at which the bed-rock was covered with sufficient sand to hold piles. This was found at a distance of about 500 feet from shore.

The line passed over a bar which would become dry at the stage of 9 feet on the Saint Louis gauge, central at the first angle counted from the upper end. The depth of water on this bar was not sufficient to float a pile-driver when work was begun, but the river began to rise soon after that, and the pile-drivers were dropped down to that bar to construct the line there while the depth of water was sufficient to float them, and the barges loaded with material. The rise continued until the river became bank-full, when the stage of 29.5 feet above extreme low water was reached about the 10th of December, and in consequence the depths and velocities along the shore increased to such dimensions that to make the connection would have been expensive, and on that account the work was deferred, with the hope that an opportunity to make it at comparatively small cost would be presented before the close of the season. The flood prevented this, however, although a single mattress was placed in the foundation of a hurdle dike intended to close just before the suspension of operations.

The work done during the first half year was constructing a detached section of the primary line, of which 2,375 feet were completed, and beginning a secondary line.

The results were remarkable, for, although the work was in an unfinished condition at the close of the season, large deposits had been made within the area that would be inclosed by the works when completed. A bar, whose crest became dry when the river fell to 22 feet above low water, extended nearly the whole length of the finished portion of the primary line, and was only about 2 feet lower as far as the piles had been driven.

Work was resumed on the 13th of March, and continued to the close of the year—at first with a small number of men, on account of the uncertainty of having favorable weather or stages of river during the early spring; but when the stage became favorable and the opening spring gave promise of weather suitable for full operations the working force was increased until about four hundred men were employed, which was maintained until about the 10th of May, when the river rose to the dimensions of a flood, causing a suspension of the work of constructing hurdles, and in consequence a reduction of the force to less than one hundred men, which continued work upon cribs to connect the piles of the primary and secondary hurdle lines with the shore.

Piles were driven for the extension of the primary line to a distance of 400 feet below its intersection with secondary line No. 4, or about 8,800 feet from its initial point on shore, and of this distance about 5,000 feet were completed, 2,300 feet additional had mattresses placed, while piles only were driven for about 1,500 feet.

Two secondary lines, Nos. 3 and 4, were completed each to a distance of about 900 feet from the primary line towards shore, and piles were driven and mattress placed for about 800 feet upon each of lines Nos. 1 and 2, and the braces were placed upon line No. 1, and work was suspended upon Nos. 1, 2, and 3, when too little sand was found on the bed-rock to hold piles, and upon No. 4 a little short of that point, leaving short gaps between the end of each and shore to be closed by cribs shown in plan, cross-section, and elevation, Plates VIII and IX, Figs. 1, 2, and 3, respectively. Of these, a section 240 feet long was built in slack water near shore above the head of work, and when completed it was floated into position by means of barges, to which it was lashed, and was placed by being loaded with a liberal supply of stone, after which the bottom in front of it was protected against possible scour by a revetment of the same material.

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Two other sections were under process of construction at the close of the year, similar to that built, with this difference, however, that the cross-sections presented the figure of isosceles instead of right-angled triangles.

The efficiency of the crib was proven, standing uninjured the severe test to which it was subjected by the drift-wood brought in contact with it during the flood of June, furnishing a cheap means of connecting both the primary and secondary hurdles with the rocky shore; the cost of which in the primary line would otherwise have been excessive, for on account of the great depths large quantities of material would necessarily have been expended in constructing any solid structure, and the experiment made with curtains showed that permeable structures held in position by anchors were not adapted for use in the swift current and upon the smooth sandy bottom found at high stages near the shore at that locality.

Hurdles continued to be constructed after the improved form introduced during the preceding year at Horseshell Bar, bracing the piles and protecting the bottom, as shown in the report of that year. An improvement was made in the method of bracing piles, by substituting a clevis, Plate VII, designed by Mr. W. S. Mitchell, for ring-bolts in holding the heels of braces in place, and the protection of the bottom by mattresses was extended to all hurdles constructed. The width of mattresses used in primary was usually twice that of secondary lines.

The strength of the hurdles has not been thus increased without a corresponding increase in the cost per linear and square unit, the extent of which cannot be determined at this time, because much of the work is unfinished; however, the increased strength justified spacing the secondary lines at 2,000 feet instead of 400 feet, and that fully compensates by reducing the number of units.

Large deposits of material have been made within the area intended to be reclaimed, and the tow-head lying to the eastward of the primary line within the space allotted to the channel has disappeared; but although these results should be satisfactory, they would doubtless have been greater had the primary line been connected with shore.

Reference is made to the report of Mr. W. S. Mitchell, resident engineer, submitted herewith, for further details.

The expenditures aggregate \$103,500.25, of which the distribution is shown in the following statement:

Material:		
Brush, primary hurdles.....	\$9,336 50	
Stone, primary hurdles.....	4,770 03	
Piling, primary hurdles.....	21,122 76	
Miscellaneous, primary hurdles.....	3,591 03	
Labor, primary hurdles.....	13,439 46	
Equipment, primary hurdles.....	10,681 59	
Subsistence, primary hurdles.....	10,142 33	
		<hr/> \$73,054 30
Material:		
Brush, secondary hurdles.....	2,071 00	
Stone, secondary hurdles.....	662 45	
Piling, secondary hurdles.....	7,410 72	
Miscellaneous, secondary hurdles.....	954 69	
Labor, secondary hurdles.....	3,427 75	
Equipment, secondary hurdles.....	5,128 22	
Subsistence, secondary hurdles.....	5,050 18	
		<hr/> 24,705 01
Engineering and contingencies.....	5,710 94	
		<hr/> 103,500 25

IV.—CARROLL'S ISLAND.

The protection was begun about the 1st of October, when a mattress-barge, with mooring-barge, was placed in position about 1,700 feet above the foot of the island. The protection contemplated placing a mattress 120 feet wide below the plane of standard low-water, with a revetment of stone up to the plane of 16 feet above that stage, and willows planted from the upper edge of the revetment to the top of the bank. Of these, only the mattress was placed, subsequent changes in currents having stopped the erosion and started a deposit outside of the work, making its immediate completion not only unnecessary, but impracticable, by building a large bar during the flood which set in about that time, connecting with the west side of the island, which became dry at several points before the water had receded below the plane of 20 feet above low water, or at 4 feet above the upper edge of the proposed revetment. This bar was not less than 300 feet wide opposite the head of the protection.

* See Plate XIV.

The mattress was built in one section, 1,695 feet long, by sinking only a part of that constructed until the whole was completed.

Being the first mattress of the kind built in this vicinity, many details connected with its construction had to be learned experimentally, which, with unfavorable weather and swift currents, caused the work to progress slowly during the season. Still the rate of construction was increased to 100 feet per day before the mattress was finished.

No other work in connection with this protection has been done; and although future changes may necessitate its completion by revetting the middle and planting the upper zones, respectively, the tendencies of the river, with the present trace of its channel, indicate that none will be needed. This work having been constructed in such close connection with Twin Hollows, east side, that the data showing expenditures of material appear only as items in the records of that work.

Mr. C. V. Mercereau, assistant engineer, who has compiled the expenditures of labor and material from those records, submits the report, to which reference is made for further details, and the quantities of material used. The exact location of the work is shown upon the accompanying tracing of the map of that locality, Plate X.

Expenditures for labor and material aggregate \$12,038.69, distributed as shown in the following statement:

146 piles.....	\$934 40
1,467.9 cords of brush.....	3,816 54
600 cubic yards of stone.....	762 00
Rope, wire, &c.....	898 35
Labor.....	3,593 40
Equipment.....	1,474 65
	<hr/>
	11,479 34
Engineering and contingencies.....	559 35
	<hr/>
	12,038 69

V.—TWIN HOLLOW, EAST SIDE.

This work has for its object the protection of the east bank of the river from the foot of Carroll's Island to the head of Beard's Island, or as far in that direction as may be found necessary, a distance that has been increasing, owing to the tendency of erosive action to move downstream. It was begun October 26, and continued uninterruptedly until December 10, and from the 17th until January 8, when it was suspended on account of unfavorable weather, to be resumed on the 21st of March, after which it was continued until the close of the year without interruption. During the year 5,925 feet of the zone below standard low-water were protected by a mattress 120 feet wide, made of sections in such lengths as were found practicable to be built under conditions due to the variable weather, stages of river, velocity and direction of current; and of the middle zone 2,350 feet were protected by a revetment, of which 1,000 feet were made of stone placed upon a loose brush mattress, and 1,350 feet were made entirely of stone. Of these 1,493 feet of the mattress and 840 feet of revetment were built during the first half of the year. The upper end of the mattress was pushed ashore by drift-wood driven by the swift currents accompanying the flood of November, and covered 150 linear feet of the middle zone.

Early in the spring season the use of this shore mat was restricted to localities at which the inner edge of the mattress lay outside of the curve of standard low-water, on account of the line having been moved by erosion after the guide-piles were driven.

During the second half of the year two sections of mattress were built and placed, one 3,800 feet long, of which 3,100 feet were placed in good shape; the remainder was damaged by the current while sinking to such extent that it was not an efficient protection. Another section was placed to cover that space. The other, 1,325 feet long, was successfully placed by means of lines attached to barges anchored along its length, but independently of it, to hold it out from shore and prevent the doubling of the outside edge under the mattress while in process of sinking, and a section of 964 feet long was afloat at the close of the year.

Many difficulties were encountered in placing the mattress in the deep, swift water found during the prevalence of the spring floods.

This form of mattress being very flexible, skillful handling was necessary to prevent folding it by the current carrying the outside edge under when that edge was sunk in advance. The difficulty became so great when the angle between the axis of the current and bank was greatest that the mattress needed additional strength to prevent breaking while sinking. This was secured by placing a grillage of poles under it, spaced to make meshes about 8 feet by 10 feet, the longer sides being parallel to the direction of the length of the mattress.

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The mattress arrested the erosion at once. The upper portion of the bank continued to be graded by the current to a suitable slope to retain a stone revetment, but that part covered by the mattress was not disturbed, although the depth of the water ranged between 40 and 60 feet along its outside edge, and impinged with excessive velocity upon the bank, between which and the axis of the current the angle was about 40°. Owing to the progression downstream of that axis the greatest impact passed over the whole length of the protected bank during the year.

On account of the high stages of the river but little use could be made of the hydraulic excavator in grading, only 2,100 linear feet having been graded by it. This afforded a sufficient trial, however, to show that it would do the work rapidly and well at low stages, when the part to be graded would be above the surface of the water.

The efficiency of the form of bank protection has been severely tested here with satisfactory results, immediately arresting the erosion of the bank, which was caving rapidly under the attacks of swift currents, due to flood stages, impinging at angles ranging from 30° to 45°, and scouring the bed at the foot of the slope, which was steeper than two upon one, to depths ranging from 10 to 60 feet at prevailing stages, or from 20 to 30 feet below the plane of low water.

Another severe and important test was made in constructing and placing the low-water mattress under nearly or quite all of the adverse circumstances that may reasonably be expected to be encountered throughout an entire working season.

The river was in flood when the work was begun in October, and continued so until December; again during the spring it was continuously above the mean stage, with swift currents, driving bodies of drift-wood to accumulate upon or under the mattress, or under and against the mooring-barge, bringing excessive strain upon the lines, mattress, and the barge.

This test has shown conclusively that it may be made continuous or in sections of any desired length under ordinary circumstances, with the river below the mean stage and stationary or falling; and that with the unfavorable circumstances of high and rising river and swift currents bringing masses of drift-wood in contact with it, sections may be kept afloat until any desired length up to 1,500 feet can be built, and such sections can be readily and safely placed in position by taking proper precautions in handling them.

The fact stated in another paragraph that the low water mattress, when placed, arrested the caving of the bank immediately, in connection with the further fact that no erosion has started upon any part of it covered by the low-water mattress, is important, because it proves that at most localities upon this section of the river the portion of the bank above standard low water may be left unprotected during a period of considerable length with safety, to be graded in part at least by currents of mean and higher stages.

Several small eddies were started in advance of the placing of the mattress, each excavating a small semicircular bay before its action could be arrested, which was done by constructing short hurdles.

Reference is made for further details of construction and quantities of material used to the report of Mr. C. V. Mersereau, assistant engineer, submitted herewith.

The expenditures made on account of works at the locality aggregate \$72,696.63, distributed as shown in the following statement:

Material:		
Brush, mattress	\$20,230 01	
Stone, mattress	3,364 85	
Piling, mattress	3,804 68	
Miscellaneous, mattress	3,008 18	
Labor, mattress	14,356 89	
Equipment, mattress	6,057 56	
Subsistence, mattress	7 496 68	
		\$58,344 39
Material:		
Brush, revetment	3,189 25	
Stone, revetment	1,945 49	
Miscellaneous, revetment	97 05	
Labor, revetment	1,025 87	
Equipment, revetment	446 74	
Subsistence, revetment	625 14	
		7,329 54
Labor, excavation	358 67	
Equipment, excavation	1,079 98	
		1,438 65
Engineering and contingencies		5,579 56
		72 696 63

VI. BEARD'S ISLAND.

The protection of this island was begun about the last of March, and was continued until the close of the year. During that period 3,850 feet of mattress were built and placed to protect the lower zone from the head of the island down stream, a distance of 3,550 feet, 300 feet having been expended in repairing a breach in the original mattress.

The first section of mattress was 3,250 feet long, of which 2,600 feet were placed without a single breach, kink, or defect of any kind, but at that point the outside edge of the mattress was torn, and by stretching down stream left a triangular-shaped area unprotected, necessitating the replacing of an extra section of mattress to protect it.

In a comparison of long mattresses this would rank second, whether its total length constructed or only that successfully placed should be measured, being exceeded only by the longest one placed at Twin Hollows, east side.

From the head of the island a distance of 2,000 feet down stream the work of constructing and placing the mattress was comparatively easy: the depths of water and the velocities of the current near shore were not excessive at any point within that space, while swifter currents farther out in the stream tended to throw the drift-wood and other floating bodies away from the shore impinging upon the bank farther down stream and presenting no cause of delay in the progress of the work until that distance had been passed in placing the mattress. At that point unfavorable changes in depths of water, velocity, and relative direction of the current occurred.

The depth, which had been moderate, increased abruptly to 40 feet along the outside of the mattress, with an increase in velocity due to that change, and the direction relative to that of the axis of the mattress was unfavorably affected by a sharp deflection of the bank through an angle of about 25°. The remainder of the mattress was placed with considerable difficulty, on account of the tendency of the current to break it by driving it against the guide piles or by doubling the outside edge under or over when its whole width did not sink together; but the section was placed with only the single break mentioned in the preceding paragraph.

The next section of mattress was started at station 32 + 50, where the velocity, direction, and depth of the current were still unfavorable. Large quantities of drift-wood were brought by the river and driven under the mooring-barge, accumulating in such masses that a line attached to the stern of the barge parted, permitting the barge to swing in towards shore, carrying the mattress and the barge upon which it was built so hard against the piles that the continuation of the construction became impracticable, and the section was launched when only 360 feet were built. This section was successfully placed, being guided to its position by lines attached to it and to barges anchored in the stream outside of and entirely independent of it. These lines, by being attached to the timber-heads and kevels upon the farther side of a barge and passing under it, did not immediately interfere with the sinking of the mattress, but held it away from shore, necessitating the paying out of the lines only after the mattress had been sufficiently loaded and had advanced towards its final resting place on the bottom.

The revetment of the bank was begun on the 18th of May, and about 1,600 linear feet were finished—the progress made keeping pace with the receipt of stone, which was retarded by the high stage of the river. Grading for the revetment was done by the current cutting the bank above the mattress after it had been placed, while the erosion below that plane was stopped. The work of grading was well done, the slope being reasonably evenly dressed and flat enough to retain stone.

This bank had been yielding rapidly to the attacks of the current before the mattress was placed, a strip of land from 600 to 800 feet wide, running the entire length of the island, having been cut away since the fall of 1880; and the erosion having progressed rapidly up to the time that the mattress was placed, shows the form of protection is efficient.

The small water-way passing around the head of the island was closed by a hurdle about 1,000 feet long, constructed in the usual form for secondary lines, except that the foot mattress extended only 450 feet from the island, on account of the small velocity of the current from that distance to its upper end.

The bar was built up to the top of the hurdle soon after it was completed, its crest being about 28 feet above low water, or within 2 feet of the general height of the bank, and its width is about equal to that of the head of the island.

Reference is made to the report of Mr. J. W. Record, assistant engineer, for further details.

The expenditures aggregate \$35,614.53, distributed as shown in the following statement:

Material:	
Brush, mattress	\$10,354 23 •
Stone, mattress	1,240 20
Piling, mattress	1,954 55
Miscellaneous, mattress	659 69
Labor, mattress	6,101 15

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Equipment, mattress.....	\$2,007 76	
Subsistence, mattress.....	3,004 20	
	<hr/>	\$25,381 78
Labor, excavation	10 15	
	<hr/>	10 15
Material:		
Stone, revetment	1,190 46	
Miscellaneous, revetment	1 70	
Labor, revetment	349 56	
Subsistence, revetment	63 13	
	<hr/>	1,604 85
Material:		
Brush, hurdles	702 00	
Stone, hurdles	122 79	
Piling, hurdles	1,325 87	
Miscellaneous, hurdles	44 04	
Labor, hurdles	394 93	
Equipment, hurdles	1,222 19	
Subsistence, hurdles	2,991 54	
	<hr/>	6,803 36
Engineering and contingencies		1,814 39
		<hr/>
		35,614 53

VII. JIM SMITH'S.

This work was begun May 23, and, although the river was high from that date until the close of the year, considerable progress was made upon the construction of the primary line, in which 426 piles were driven, extending from shore at its head 1,000 feet down stream; of that 800 feet of mattress, 50 feet wide, were placed, and 500 feet were hurdled, which was done by wattling to the depths to which that form of construction could be economically used, and in greater depths a wattled curtain, shown in Plate XIII, was placed in the base, of which the poles extended to the surface of the water, to be incorporated in the wattling upon the piles; of this curtain 250 linear feet were placed.

The river was in flood during the entire time that this work was in progress, and much time was consumed in preliminaries of erecting quarters and making surveys that were needed in locating the line of the primary hurdle, in accordance with its representation on the map, and the progress made in constructing the hurdles was small compared with that which could have been made under favorable circumstances, on account of the swift currents, great depths, and the large masses of drift-wood which the high and rising river brought to oppose the progress of the workmen.

The results, however, fully compensated for expenditure, as shown by the deposits that were made about the close of the year, which raised a bar equal in width to the length of completed hurdle, and in height to that of the wattling immediately in rear of the line, thence dipping down stream it may be traced by the shoaling to the lower end of the locality.

The report of Mr. John O. Holman, assistant engineer, is submitted herewith, to which reference is made for further details of construction and quantities of material expended.

The expenditures aggregate \$11,068.37, distributed as shown in the following statement:

Material:		
Brush, primary hurdles.....	\$513 00	
Stone, primary hurdles.....	349 70	
Piling, primary hurdles.....	2,059 33	
Miscellaneous, primary hurdles	139 64	
Labor, primary hurdles	1,413 91	
Equipment, primary hurdles.....	1,973 11	
Subsistence, primary hurdles	2,513 40	
	<hr/>	\$8,968 08
Material:		
Brush, secondary hurdles	67 50	
Piling, secondary hurdles.....	76 57	
Miscellaneous, secondary hurdles.....	27 64	
Labor, secondary hurdles.....	24 08	
Equipment, secondary hurdles.....	132 03	
Subsistence, secondary hurdles.....	279 27	
	<hr/>	607 09
Engineering and contingencies.....		1,499 19
		<hr/>
		11,068 37

VIII. ENGINEER DEPOT.

During the first half of the year the work of constructing and repairing barges, barge-flats, pile-drivers, quarter-boats, portable shanties for quarters, and small boats appertaining to the equipment, not only for these works but for general use upon the river between the Illinois and Ohio rivers, was done at the foot of Marine avenue. The depot of supplies of rope, iron, spikes, nails, bolts, and other items belonging to the class known as miscellaneous material, was also established there in rude shanties too small to furnish protection to the stock of material and subsistence stores necessary to be carried. These shanties were built of common boards, and covered with the same, upon ground that the river had recently made by depositing a portion of its sediment, and which its erosive currents were rapidly removing towards the sea.

A depot was established on the east side of the railroad in front of the Saint Louis Arsenal, consisting of two store-rooms—one for material, the other for subsistence—buildings for carpenter and blacksmith shops, oakum and oil rooms, and offices for clerks in charge of subsistence, of working parties, and material at the depot. Of these the blacksmith shop and oakum room were moved from Marine avenue; the others were constructed from new material.

The work was begun January 21, and the first stores were received there about the 1st of March, when the old stand at the foot of Marine avenue was abandoned, with the exception that repairs of barges were continued there a short time after that, until some dangerous parts of old wrecks could be removed from the front of the depot.

The equipment available for works between the Illinois and Ohio rivers was increased during the year by the addition of eleven pile-drivers, one hydraulic excavator, two mattress-barges, thirty-seven portable shanties for quarters, and eighty small flats constructed, and twenty-nine barge-flats altered from coal barges, of which only two were purchased this year, the others having been on hand from the purchase of the preceding year; forty-two yawls and eighty-two skiffs purchased, while the steamers A. A. Humphreys, Anita, steam-launch Hornet, pile-driver No. 2, and barges Nos. 12, 13, 14, 17, 18, 19, and 20 received extensive repairs, which, upon being added to that on hand, made the equipment and quarters available for use in connection with these works sufficient to accommodate a force of about 1,500 laborers.

Reference is made to the report of Mr. C. L. Stevenson, clerk in charge of material and working parties, herewith submitted, for further details of construction.

The expenditures on account of the operations in connection with the depot and equipment aggregate \$140,134.11, distributed as shown in the following statement:

Humphreys	\$4,408 52
Anita	809 66
Hornet	286 92
Barges.....	87,038 44
Pile-drivers	29,461 68
Hydraulic excavator	8,538 31
Ways for mattresses.....	6,461 17
Quarter-boats, quarters, shops, &c.....	31,904 92
Skiff, &c.....	14,119 88
Tools and appliances	7,014 61
Total.....	140,134 11

IX. PROCURING MATERIALS.

Procuring the materials, brush, stone, and piles constituted a separate division of the work, in which nearly the whole time of the steamer A. A. Humphreys, ten model barges, and sixteen barge flats was consumed.

Brush was procured by hired labor, a royalty being paid to the owners for permission to cut and remove it.

During the first half of the year a party was organized under an overseer and kept at work on the islands and bars between the head of Fish Bend and Jones' Point, until about the middle of November, when it suspended work on account of high-water. It was reorganized and set at work in the Missouri River about the 1st of March.

Two other parties were organized and set at work in the Mississippi River, one about the 10th of March, which worked in the vicinity of Fish Bend, the other about the last of April and worked in the vicinity of Cabaret and Wilson's Islands. The three parties consisted in the aggregate of about three hundred men. Those in the Mississippi River continued at work until June 1, when they were disbanded on account of the lowlands from which they were procuring brush having been overflowed. That in the Missouri River, having higher grounds, worked there until the 23d of June, when the brush that was available at high stages of water having been procured, it

was transferred to Jones' Point, Mississippi River, where it remained until the close of the year, procuring poles and such brush as was available.

Of the 25,000 cords procured 14,500 cords came from localities on the Mississippi River, distributed as follows: Liberty Island and Towhead, 6,800 cords; Fish Bend and vicinity, 5,000 cords; Cabaret Island and vicinity, 1,700; and from the immediate vicinity of the works, 1,500 cords; and from the Missouri River, 10,000 cords; distributed as follows: Little's Island, 2,100; Hog Island, 4,900 cords; and Green Island, 3,000 cords.

The average distance towed is estimated to be equivalent to 40 miles of upstream towage; and to reach navigable water the average haul is estimated at about 1 mile. These distances are greater than brush has been towed or hauled during any previous year, but not greater than may be expected in the immediate future. They are the variables of the elements which make up the cost of procuring this material. Cutting and loading can be done with a nearly constant expenditure of labor and with only such variation in cost as may be due to that of the rate of wages.

Pile timber was procured by purchase in open market; 11,579 sticks, measuring 354,571 linear feet, were delivered in rafts at the works, and 5,845 sticks, measuring 204,707 linear feet, were delivered upon barges belonging to the United States at landings between Turkey Island and Big Eddy, the average distance of upstream towage being about 65 miles.

Of the stone used in the works, 7,487.6 cubic yards were procured at Chester, Ill., and 15,733.90 cubic yards were procured from quarries near the works located at Bushberg, Kimmiswick, and this city, by purchase in open market, delivered upon barges belonging to the United States, and was towed to the different localities at which it was used, an average distance of 30 miles.

Miscellaneous material was procured by purchase in open market in large quantities, to secure the advantages of wholesale prices, and to keep a supply in stock for distribution among the works. This item includes lumber, bolts, iron, spikes, nails, rope, and yarn. The materials named were kept constantly on hand, and in sufficient quantities to furnish each of the works with an ample supply.

In addition to the towing needed in procuring material used, the steamer A. A. Humphreys has handled all barges, pile-drivers, quarter-boats; transported all miscellaneous material, subsistence stores, and ice needed in connection with the works, and still it has not been at all pressed, the distribution of its service showing that it was idle about 7 per cent. of the entire time that it could have worked, exclusive of the thirty-six hours per week, from Saturday night to Monday morning, allotted to cleaning boilers, making minor repairs, and rest.

The comparative ease with which the steamer accomplished the work devolving upon it is due to a combination of several causes, of which the following are prominent: First, it was furnished with two electric lights, one a reflector revolving to illuminate distant objects, and to be used in making landings at the works and running close dangerous reaches of river during dark nights, and the other to illuminate the fore-castle for use in making up tows, coaling, and handling material and stores transported at night, thus preventing the interference of darkness with the length of a working day. Second, the loss of time, in making landings for the purpose of learning the wants of assistants and other persons having charge of working parties served by it, was reduced to a minimum by the use of a code of signals, by many of which the service desired could be communicated at a distance, enabling the boat to proceed directly with the work instead of landing to receive instructions. Third, the telephone connecting each of the works, the depot and office, was freely used during the last two months of the year, in communicating with persons in charge of construction, to learn the wants of each locality, in directing the movements of the boat, and in having supplies of material, subsistence, fuel, and ice delivered at the depot or other convenient points, and contributed largely to securing prompt service with the least possible expenditure of work.

X. WEATHER AND RIVER STAGES.

The year was not a favorable one either for procuring material or for construction. The river, which was 23 feet above low-water on the 1st of July, declined slowly until about the 1st of September, when the gauge indicated 8½ feet above the same plane. It then rose to the 20-foot stage by the middle of October. This flood continued until the 29½-foot stage was reached, on the 20th of November, and then slowly receded to 17 feet above low water, which was the stage at the end of December.

The flood retarded progress in all field operations by overflowing the low grounds which produced the willows and other saplings suitable for brush. On this account the season was permanently closed at some localities considerably earlier than was made necessary by the weather. Another result of the prevailing high stage was the swift current and deep water at the works, bringing immense masses of drift-wood, parts of which became entangled in the piling of unfinished hurdles, collected under

mattresses, or were driven with such force against barges and other vessels of the equipment that they were in constant danger of being sunk by detached logs or grounded by the accumulations under them. The first half of the year was not made unfavorable by floods alone, the weather was excessively hot during the months of July and August, after which heavy rains followed, continuing until the 10th of December or until the season had closed at Arsenal Island, Horsetail Bar, and Twin Hollows, west side.

About the last of February, when preparations to resume work were nearly completed, another flood came suddenly, beginning on Monday the 20th, after about 6.75 inches of rainfall during Saturday night and Sunday. The river rose 0.8 of a foot in twenty-four hours ending at 1 p. m. Sunday, 8.75 feet from that to the same hour Monday, and 7.95 feet additional before Tuesday the 21st, at the same hour. During part of Monday it rose at the rate of 12 inches per hour.

The flood reached its extreme height Wednesday the 22d, when the stage of the river was 28.25 feet above low water on the Walnut-street gauge, Saint Louis. It did not seriously injure the works, but by overflowing the low lands upon which willows suitable for brush grow, delayed the resumption of active field operations until the ground became firm enough to sustain teams after the recession of the flood, which was about the 3d of March, after which the progress made with all of the works was uninterrupted until about the last of May, when the river again left its banks in the low lands and retarded progress at all of the works by bringing large masses of drift-wood to accumulate against piles while the works were in an unfinished state, by submerging piles that had been driven for hurdles, by causing swifter currents in which barges, pile-drivers, and other vessels used in connection with the work had to be handled, and by reducing the available supply of stone, brush, and piles, overflowing a portion of the loading room at the quarries from which stone was procured and the ground upon which brush and piles grow.

XI. QUARTERING AND SUBSISTING LABORERS.

Prior to this year, when operations were upon the basis of smaller allotments to be expended, parties of laborers away from Saint Louis were subsisted by the United States furnishing suitable boats, shanties, or tents for quarters, and making arrangements with suitable persons to furnish the necessary outfit, and board employes, furnishing substantial fare at agreed rates, to be collected from such employes at the pay table. That system worked satisfactorily while the number of employes remained small, say three hundred or less laborers; suitable persons to board that number were easily secured; but when the demand was suddenly quadrupled, by the enlarged field of operations inaugurated at the beginning of this year, it could not be supplied, and on that account the progress made during the first half of the year was less than it otherwise would have been. For the reasons stated, that system was abandoned at the close of the first half year; another was formulated during the winter and introduced at the resumption of operations in the spring, in which the United States furnishes the outfit complete, and subsists the employes at all localities at which they could not secure other satisfactory arrangements, making suitable reduction in their rate of compensation to cover extra expenses incurred on that account. Introduced about the 1st of March, it was in operation about four months of the year, a period of sufficient length to thoroughly test its adaptability to the wants in connection with operations for improving the river based upon large appropriations.

The dissatisfaction among employes on account of subsistence has been less than usual since this system was introduced, although that did not receive consideration in determining the change. The great benefit that was hoped would be derived from the new system of subsisting lies in the complete control over the strength and movements of working parties that it gives to the engineer. The hope that this control would be attained induced the change of systems, and that hope has been fully realized.

XII. COMMUNICATIONS.

Prior to the 1st of May, communications between the office, the depot, and the works were made through the steamer A. A. Humphreys, using, in cases of emergency, the local trains on the Iron Mountain and Southern Railway. These trains not carrying mail, they were necessarily by messenger, the expense of which was one of the least objections to the method; but the delays in learning and supplying the wants at the works, necessarily incident to these slow methods are of much greater importance.

A telephone line was established between the United States Engineer Office, No. 404 Market street, Saint Louis, and the works at Twin Hollows, west side, with intermediate stations at the supply depot and Horsetail Bar. This line has since been extended to the mouth of the Meramec River. This brought the depot and works located upon the west bank of the river into direct communication with the office, and each with the others, while those upon the east side of the river could readily send mes-

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sages by small boat to the nearest station, or, when important, the resident engineer could come to the nearest station for personal interview.

The telephone was freely used from the date upon which it was opened by all who were charged with supervision of construction in reporting progress made and difficulties encountered, asking advice, making requisitions for material and subsistence, employing laborers and others, and in reporting every matter of importance relating to their respective works; and it was also to a large extent the means used in directing movements relating to these works, based upon full information received through the same means.

The cash value of the telephone can scarcely be estimated, because the sum of the savings due to its use cannot be converted into a cash equivalent; however, it helped to reduce to a minimum the distances that the steamer had to run in delivering material and other service required, and this is only one of many items which could be enumerated. Broken machinery has been repaired, making requisition through the telephone for the parts needed to replace those broken; forms of construction have been sent, discussed, and modified in accordance with necessities; in particular instances lines of hurdles have been located after full discussion of the merits of several preliminary ones examined; raftsmen, when arriving out of time, rely upon this source for instructions relating to the delivery of piles; the details of expenditure, of labor, and material for insertion in weekly reports have been made and checked. This enumeration is incomplete, but is sufficient to show the value of the telephone for use in connection with the supervision of the works.

In this connection the small boats, including skiff, yawls, and flats, have been of great service in delivering promptly small quantities of material, subsistence, tools, and parts of machinery, for which requisition had been made through the telephone, which otherwise would have been delayed by waiting for the steamer.

The works being situated below the supply depot, such delivery could be readily made, and the small boats were returned by the steamer, while the oarsmen returned by train, when the time lost in waiting for the boat would be worth more than the cost of a ticket by rail.

Very respectfully, your obedient servant,

D. M. CURRIE,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

B.

ARSENAL ISLAND.

REPORT OF MR. A. F. FREIS, ASSISTANT ENGINEER.

ST. LOUIS, MO., July 22, 1882.

MAJOR: I have the honor to submit herewith a report of the operations of the works at Arsenal Island for the fiscal year ending June 30, 1882.

ARSENAL ISLAND PROTECTION.

The work of completing the unfinished portion of the revetment at Arsenal Island was begun about the 1st of November, in obedience to instructions contained in your letter, of which the following is a copy:

"ST. LOUIS, MO., September 28, 1881.

"SIR: It will be necessary, before the close of the present working season, to complete that portion of the Arsenal Island revetment which was begun last year and left unfinished.

"You will please cover with riprap the upper part of the bank to a height of 20 feet above low water of 1863, procuring the stone as soon and as rapidly as convenient from the Southern Illinois penitentiary at Chester.

"You are requested also to ascertain whether the river bank below the old work has receded far enough to justify its continuation downstream, and report the results of your observations.

"Very respectfully, your obedient servant,

"O. H. ERNST,
"Captain of Engineers."

"Mr. D. M. CURRIE,
"Assistant Engineer."

Owing to the demand for stone at the quarry, it could not be secured in quantities sufficient to justify beginning this work, after supplying the other localities in this

vicinity, until about the 1st of November, when, as several barge loads had been secured, work was begun at the lower end of that portion of the revetment that extended to the top of the bank. The stage of the river was then about 23½ feet on the Walnut-street gauge at Saint Louis, or 3½ feet above the plane to which the upper edge of the revetment was to be extended, and, in consequence, the work could not be finished; but by constant use of the sounding-rod, the riprap was distributed very nearly in equal thickness over the zone between the upper edge of the old revetment, which was found at about the 10-foot stage, and the plane 20 feet above low water.

The work was continued until the 17th day of November, or fourteen days after it was begun, when, on account of the high water, it was suspended to await a more favorable stage, and as the general suspension of field operations followed soon after, this became final for the season. During the two weeks that work was in progress, 1,400 linear feet of the revetment were raised to the height designated in the letter of instructions, but the stone may need some redistribution to complete the work. The points are designated on the tracing by the letters *a b*, Plate II. This leaves 2,100 linear feet unfinished of the 3,500 begun in 1879.

The survey of the island, to determine whether the river bank below the old revetment has receded far enough to justify the continuation of the work downstream, was made by Mr. Wm. S. Mitchell, assistant engineer, from which the present location of the bank was determined, as shown upon the tracing.

Upon comparing the proposed shore line below the revetment with the bank, as shown on the tracing, it is found to fall on the outside for about one-half the distance, and for the remainder of the way it runs a few feet inside of the bank, showing it has receded far enough to justify the continuation of the work.

The work of completing the remaining 2,100 linear feet of partial revetment was resumed on March 6, with a small force of men, and continued until May 6, when it was completed; having been carried to a height corresponding to a 20-foot stage, *b c* representing the points on the tracing, thus making a total of 4,200 linear feet of revetment placed upon the island.

An eddy which was eroding the bank to a great extent having formed at the lower end of the revetment, a series of cross-hurdles were placed to destroy the action of it. There were two lines placed at first, when it was found that the piles had deflected the eddy farther down stream, and that it was eroding the bank back of those lines; a third line was then determined upon, whose shore end would be such a distance down stream as to be outside of all action of it, and whose outer end would cut the eddy when it made its turn towards the shore. After driving this line and placing wattling upon the three it was found to have effectually broken the current, and a deposit commenced to form at once. The work of constructing these lines of hurdles commenced May 6 and continued until May 17, when they were completed; the aggregate linear feet of wattling contained in the three lines being 325; the greatest depth of water found at the end of the lines during construction being 36 feet. The depth found at the same place at the end of the fiscal year being 24 feet, the soundings having been reduced to the same stage, soundings taken at other points in the line show a corresponding deposit.

The driver proceeded on May 15 to drive a line of guide-piles to assist in the construction of a mat, the piles being driven 15 feet between centers and at such a distance from shore as to allow the placing of a foundation mat 40 feet in width, and whose inner edge when sunk would be in standard low water.

This work continued without interruption, with an increased force from May 15 until the end of the fiscal year, when there had been 2,800 linear feet of mattress constructed, 2,450 linear feet of which was placed on the bottom in good condition, the remaining 350 feet being lost through the giving way of the piles, which allowed the current to catch the mat and tear it loose.

The points are represented on Plate II by the letters *a, b, c*, and *d*.

This mat was constructed directly on the water, the outer edge of it having been lashed up to the line of guide piles about 1 foot from the surface so as to prevent the current from catching it, while the inner edge was allowed to rest on the water. It is composed of two layers of brush placed upon a frame grillage, composed of continuous poles laid 6 feet apart and running the length of the section, held by cross-pieces at intervals of 6 feet. Upon this grillage a layer of brush is placed at right angles to the current, then a second layer is placed on top of this parallel to the current. Upon top of this layer poles are placed directly over and parallel to the cross-pieces of the frame and the whole bound firmly together. There were also three lines of wire placed the length of each section of the mat, a round turn having been taken around each cross-piece of the frame. The mat was built in sections varying between 450 and 724 linear feet.

After completing this mat the bank will be protected with riprap, starting from the inner edge of the mat and extending up to a 20-foot stage.

Cross-sections of the two different features of the revetment are shown on Plate II, Figs. 1 and 2.

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The following statement shows the number of linear and square feet of revetment and mat, constructed at Arsenal Island during the fiscal year ending June 30, 1882:

Three thousand five hundred linear feet of revetment of about 40 feet in width, or 140,000 square feet.

Two thousand eight hundred linear feet of foundation mat about 40 feet in width, or 112,000 square feet.

MATERIAL USED IN CONSTRUCTION.

Stone.....	cubic yards..	5,671.37
Brush.....	cords..	935.45
Piles (301 piles).....	feet..	10,692
Wire No. 12.....	pounds..	211
Rope.....	do....	5,085
Spikes.....	do....	450

Very respectfully, your obedient servant,

A. F. FREIS,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

C.

HORSETAIL BAR.

REPORT OF MR. A. F. FREIS, ASSISTANT ENGINEER.

SAINT LOUIS, Mo., July 22, 1882.

MAJOR: I have the honor to submit herewith a report of the operations of the works at Horsetail Bar, both on the Missouri and Illinois shores, for the fiscal year ending June 30, 1882.

First, in reference to the works on the west side, or Missouri shore, the present condition of which is represented on the tracing of the locality, Plate IV; also the total amount of construction placed upon the same, different letters being used to designate it, the notes of which are placed upon the tracing.

The primary line on the west side of the river was located July 16, from its upper end near the mouth of the River Des Peres, to the outer end of dike 1, points on the line being fixed by clumps of piles. The lower part of the line being located August 10, the construction of this line was pushed forward vigorously from the time of the location of the first section until about the latter part of September, when they were compelled to desist on account of the high stage of water; the piles driven in that time having extended for a distance of 6,075 feet, using 1,371 sticks of pile timber. There were also placed upon the primary line 5,311 linear feet of foundation mattresses, starting from the river Des Peres and running down to secondary hurdle No. 3; starting again 170 feet above line No. 5, and extending to the end of the line, 1,000 linear feet of curtains; starting 50 feet above hurdle No. 1, and extending to hurdle line No. 3, 890 linear feet of plank gates; starting 250 feet above hurdle line No. 5, and extending to within 50 feet of No. 6, 3,650 feet of wattling, of which 450 feet is placed at the head of the line, the remaining 3,200 feet starting 50 feet above line No. 6; and running to the end of the line. The discrepancy between the figures given and the measured distance on the map is owing to lapage—that portion of the line between secondary lines Nos. 3 and 5 being in an unfinished condition on account of the submergence of the piles.

Work was resumed on the secondary hurdles on July 11, and continued until August 20, when they were completed with the exception of a passage-way for barges left between the primary line and the outer end of Nos. 2, 3, 4, 6, 7 and 8. Nos. 2 and 7, however, were afterwards extended to the primary line, secondary line No. 2 having been extended 174 feet, using 17 piles, 96 linear feet of curtains, and 92 feet of plank gates. No. 3 has been extended 266 feet, using thirty piles and 312 linear feet of curtains. No. 4 has been extended 348 feet, using forty-two piles and 408 linear feet of curtains. No. 5 has been extended 509 feet, using one hundred and forty-seven piles and 598 linear feet of curtains. No. 6 has been extended 581 feet, using one hundred and twenty-two piles, 620 linear feet of curtains, and 63 linear feet of plank gates. No. 7 has been extended 740 feet, using seventy-six piles, 840 linear feet of curtains, and 30 linear feet of plank gates. No. 8 has been extended 750 feet, using one hundred and seventy-seven piles, 512 linear feet of curtains, and 314 linear feet of wattling. No. 9 has been extended 72 feet, using four piles and 72 linear feet of gates. These

works stood intact up to June 26, when the main row of piles of a section of the primary line, consisting of about 125 linear feet, gave way. This break started at hurdle line No. 8, and extended up stream for the distance mentioned; the points are represented on the map by the letters *k* and *k*." This break was due to the erosion of the bottom, the depths of water given by soundings, ranging between 36 and 52 feet, the reading of the Saint Louis gauge being 28.9 feet. No attempt was made to repair it, as the works were all submerged.

There has been no work done on the Missouri side since its discontinuation in the latter part of September, 1881.

Appended is a tabular form of the hurdles constructed for the present fiscal year:

Location of hurdles constructed on Missouri side during fiscal year ending June 30, 1882.

Primary and secondary number.	Piles driven.	Foundation map placed.	Curtains placed.	Wattled hurdles.	Pine gates placed.	Total hurdles.	Completed.
		<i>Lin. ft.</i>	<i>Lin. ft.</i>	<i>Lin. ft.</i>	<i>Lin. ft.</i>	<i>Lin. ft.</i>	<i>Sq. ft.</i>
Primary line	1,371	5,311	1,000	3,650	890	5,300	91,310
Section line, No. 2	17		96		92	174	6,720
Section line, No. 3	30		312			266	8,246
Section line, No. 4	43		408			348	11,484
Section line, No. 5	147		598			509	17,312
Section line, No. 6	122		620		63	581	14,825
Section line, No. 7	76		840		30	740	17,020
Section line, No. 8	177		512	314		750	16,574
Section line, No. 9	4				72	72	1,308
Total primary hurdles	1,371	5,311	1,000	3,650	890	5,300	91,310
Total secondary hurdles	615		3,386	314	257	3,440	92,249
Total	1,986	5,311	4,386	3,964	1,147	8,830	183,559

ILLINOIS OR EAST SIDE.

Work at this locality was in progress at the beginning of the present fiscal year, a small force being engaged in reconstructing the primary line. This force was not increased until July 10, on account of the high-water that prevailed up to that date.

The work on the primary line had reached a point 200 feet below its intersection with secondary line No. 21, on the 1st of July, and was continued from that point downstream without interruption until about the last of September, when it was suspended, as the river had risen again, the line having been completed to its intersection with secondary hurdle No. 29, with a double row of piling driven from that point down to connect with secondary No. 30, the length of the line being 4,100 feet, expending thereby 1,052 piles, 2,585 linear feet of foundation mattress, 2,976 linear feet of curtains, and 425 linear feet of wattling.

The depths of water upon the line above secondary No. 24 were excessive, averaging between 24 and 26 feet, with the river at a 24-foot stage. They were, however, only equal to the average depth found in this vicinity since the works began, the current being, however, more favorable in velocity and direction than at any preceding time.

The plant having been increased the latter part of July by five pile-drivers and two barge-flats, a corresponding increase was made in the working force.

The work of repairing and extending secondary lines was commenced during the month of August, that of secondary 27 on the 18th, 29 on the 29th, while that of 30 was not commenced until September 6.

The equipment was increased about the 1st of September by three new drivers, which continued working at these points until September 27, when two of them were transferred to commence work at Twin Hollows. These were followed about the 1st of October by all excepting four of the drivers, the corresponding part of the force going with them. The force remaining continued work upon these lines until the last of October, when the pile-drivers and part of the force were transferred to line No. 18, to repair and strengthen it, the remainder of the force being transferred to the works at other localities.

Advantage was taken of the high stage of water during the month of October to construct line No. 30 across the bar, which was then submerged, but this water caused

* Large scale map not forwarded.

some damage to secondaries Nos. 27 and 29, and retarded their progress. The four pile-drivers, with the requisite equipment, continued the work of repairing and strengthening secondary hurdle No. 18 until the latter part of November, when the barges and all the drivers, with the exception of one, were placed in winter quarters. The repairing of this line continued until December 6, when the line had been completed to within 350 feet of the primary line. The plant was then sent to harbor, and the force disbanded on December 4. Work was not resumed again until March 20, when the plant, consisting of three drivers and a barge, were towed to the works, but the high winds prevailing during that season of the year caused such damage to the plant as to prevent active operations from being resumed until March 27, when the work consisted of repairing breaks in the primary line and secondary line No. 18.

In making an examination of the works it was found that the primary line had been damaged to a greater or less extent from secondary line No. 18 to line No. 24, the breaks occurring not being caused so much by the scouring out of the piles as by the drift and ice flowing against them during the winter and early part of the spring, which forced the piles over and broke them, thereby permitting such a volume of water to pass through as to eventually scour them out. The two principal breaks occurring in the primary line were between secondary hurdles 20 and 22, and midway between 22 and 24, that between 20 and 22 being 400 feet, starting 260 feet below line 20, and extending downstream; that between Nos. 22 and 24 being 450 feet, starting 150 feet below line No. 22, and extending downstream. The points are indicated on the tracings by the letters *m, n, o, p*. Operations were first resumed upon the gap between lines 20 and 22, the force having been able to work to greater advantage there than on the one below, as the piles at each end of this break were nearly all submerged. The three drivers continued work upon this gap from March 27 until April 1, when a double row of piles had been driven. Two of the drivers were then moved to the lower gap, the water having fallen, while the other driver commenced driving a third row of piles, starting from dike 3, the intention being to extend it to the lower end of the second gap. The object of this row was to facilitate the placing of a foundation mattress, that is to extend at least 30 feet in front of the main row. This line was run down stream for a distance of 1,300 feet.

The designation of the rows of piles is as follows: the middle being the main row the piles of which are driven 6 feet from center to center; the back one the bracing row, with the piles driven 12 feet from center to center, and 18 feet back of main row; the other, the outer, with the piles driven 24 feet from center to center, and 20 feet in front of main row.

The work of construction on the break between lines Nos. 22 and 24 continued until April 15, when a double row of piles had been driven. The driver was then moved to the section of primary line between secondary lines 19 and 20, continuing work thereon until the 22d, when they were placed upon secondary line 18 to repair the gap of 350 feet left open at the end of the first half of the fiscal year. The remaining driver continued work upon the outer row until April 22, when it was compelled to desist, as the water had risen so as to submerge all the lower end of the works. It was then moved to the primary line above secondary line 20 to replace all piles that had been broken between that point and line No. 18, continuing to work upon the same until May 6, and from that time until May 29 it was utilized placing booms on secondary line 18 and primary line.

The two drivers that had been moved to hurdle line No. 18 continued work upon this line until May 6, when all the piles necessary to close the gap had been driven. They were then transferred to other works, as they could not be used to further advantage here.

The number of linear feet of piles placed upon the primary line was 19,483, of which 14,944 feet were driven, consisting of 360 piles, and the remaining 4,539 feet, 160 piles, were used as booms and stringers. There has also been placed 1,170 linear feet of foundation mattress, starting 100 feet below dike 3, and extending 200 feet below line No. 21; 1,200 linear feet of plank gates starting from line 18 and extending to line 20, starting again 350 feet below line 20, and extending downstream for a distance of 100 feet. On the tracing *a, b, c, d* represent where the gates were placed, while *e, f* represent that of mattress.

The repairs on secondary line 18 were completed May 15, thus leaving the line in good condition out to the primary line.

This line gave way again on June 9 and 25 respectively, the first break occurring 300 feet and the other 800 feet from shore. These breaks were each about 100 feet long. They were due to the great quantity of drift collected against the line, and forced the piles over, represented by *o, p, r, s*.

The driver retained in harbor here was placed in requisition at once, and the work of repairing the gaps commenced and continued until the end of the fiscal year, when a double row of piles had been driven in the outer gap.

There has been placed in line No. 18, 8,249 linear feet of piling, 6,735 feet of which were driven, consisting of 168 piles. The remainder, 1,514 feet, 51 piles, were used as

stringers and booms, 300 linear feet of foundation mat, 346 linear feet of plank gates. The two points are represented by *m n*.

The force, with the exception of a few men, were laid off on May 29, those retained being employed in the construction of gates. This force was not increased again during the fiscal year.

The following is the manner in which the plank gates have been placed: The gates having been constructed on the bank they were then placed upon a barge and towed to the works, where they were launched and floated to the place designated for them. Strong hinges having been previously placed upon one edge of the gate, these were made fast to the piles or stringers; the other end of it is then forced under water until the current catches it and places it against the piles.

In such places where the current comes directly against the gates they have been found effective, but when it cuts them obliquely some difficulty has been experienced in keeping them down against the piles.

The gates are made of yellow pine, the frames being constructed of 8 pieces of 2 by 6 inches, which are vertical when in position, with inch boards placed upon them diagonally, a space having been left between consecutive boards equal to the width of the board; they are 32 feet in length, and of a depth corresponding to the water of a 20-foot stage. See sketch showing elevation and section of gate in position, Plate V.

One noticeable feature of the work is, that when a line has been broken and a channel scoured, this channel persists in remaining for successive seasons after the line has been repaired.

The following table shows the location, extent, and character of the work done in constructing primary and secondary hurdles during the fiscal year:

Location of hurdles constructed on Illinois shore during fiscal year ending June 30, 1882.

Lines.	Piles for bracing.	Piles driven.	Foundation mat placed.	Curtains placed.	Wattled hurdles.	Pine gates placed.	Total hurdles completed in repairs and extension.	
	No.	No.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Lin. ft.	Sq. ft.
Primary line.....	160	1,412	3,755	2,976	425	1,200	4,300	95,070
Secondary line No 18.....	51	402	695	672	450	346	1,461	23,611
Secondary line No. 27.....		335	150	1,128	225		1,215	27,510
Secondary line No. 29.....		205			625		625	9,225
Secondary line No. 30.....		531	680	100	1,048		2,033	31,425
Total primary hurdle.....	160	1,412	3,755	2,976	425	1,200	4,300	95,070
Total secondary hurdle.....	51	1,473	1,525	1,900	3,278	346	5,334	91,770
Total.....	211	2,885	5,280	4,876	3,703	1,546	9,634	186,840

Tracing plate No. IV shows the condition of the bars formed within the constructed works as existing on June 30, in 1881 and 1882—that of 1881 being shown in a broken line, while 1882 is shown in dotted outline, the stage of water for presentation being taken at 12 feet, while some of the bars that existed at the end of the last fiscal year made their appearance at a higher stage of water than at present.

The general deposit formed inside of the works during the present fiscal year has been more evenly distributed than heretofore.

The following statement shows the material used in the works of construction at Horsetail Bar, for the fiscal year ending June 30, 1882:

MATERIAL USED IN CONSTRUCTION.

Brush.....	cords..	1,755.54
Stone.....	cubic yards..	1,436.54
Piles (2,636 piles).....	feet..	87,298
Rope.....	pounds..	21,113
Spikes.....	do.....	4,960
Wire, No. 12.....	do.....	10,717
Iron.....	do.....	19,740
Nails.....	do.....	6,485
Bolts.....	number..	4,126
Hinges.....	do.....	316
Lumber.....	feet..	36,084

AUXILIARY WORK.

Upon the approach of the low stage of water, about the middle of September, the river fell faster than the bar was cut away; the current did not concentrate in one channel, but spread over the whole area between the primary hurdle lines.

Three distinct depressions were perceptible in the reef, in each of which there was a minimum depth of about 6 feet when the river reached the 24-foot stage. Channels passed through each of these depressions; one, flowing near to and parallel with the east primary line to a distance of 2,500 feet below dike No. 4, crossed the reef at that point, passed to the Missouri shore and reunited with the other channels at the point of the bluffs below Jefferson Barracks; a second channel, which could be run by descending boats, diverged from the former opposite secondary line No. 24, and crossed the reef in front of the old quarry on the barracks reservation; the third channel passed near the works on the west side of the river, and crossed the reef near the lower end of the primary line on that side. The best channel for navigation alternated between these ways, either of which had a greater depth of water than was in the river below, but the one on the west side of the river was decidedly the most desirable both for navigation and for the works.

The river, however, showed a tendency to concentrate in the eastern channel, threatening the destruction of the works on that side by the scour which would take place along the primary line. To prevent this and secure sufficient depth in the navigable channel, the opening of a channel through the reef was determined upon and the work was done—the work ending September 17—by means of water jets from the Worthington pumps on 4 pile drivers.

The drivers were firmly lashed together, two abreast, with the leads as nearly as possible in juxtaposition, and the 4 jets brought together. Three anchors were laid, by which the drivers were held in the line selected, crossing the narrowest part of the reef, and they were drawn backwards and forwards across the bar by means of the steam windlass connected with the crab machinery of one of the drivers. The greater part of the work was done while they were passing up stream. Work was begun on the 12th of September at 1 p. m., when, with 9.8 feet on the Walnut Street gauge, there was only 6 feet of water on the reef, and that only in a narrow channel. Soundings were taken at two o'clock on the following day, when 8½ feet was the least depth found, the river having risen 0.3 of a foot in the mean time, and this depth was found in a channel of sufficient width for the largest tow on the river. The work was continued during the remainder of the week with marked success. The least sounding obtained on the 17th of September was 9½ feet, the river having risen 1.3 feet since work was begun. On October 10, with the water at 20½-foot stage at Saint Louis, the least depth in this channel was 24 feet, showing a scour of about 7 feet since September 12.

Very respectfully, your obedient servant,

A. F. FREIS,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

D.

TWIN HOLLOWES, WEST BANK.

REPORT OF MR. W. S. MITCHELL, ASSISTANT ENGINEER.

TWIN HOLLOWES, WEST SIDE, July 20, 1882.

MAJOR: I have the honor to submit the following report of the operations, for the improvement of the Mississippi River near Twin Hollowes, Missouri, for the fiscal year ending June 30, 1882:

That portion referring to the work done previous to January 1 is taken from the report of Mr. D. M. Currie, superintending engineer, for the half year immediately preceding that date.

An effort was made to begin the work at this point about September 1, 1881, but on account of a lack of facilities for subsisting men in large numbers in the vicinity, it was found impracticable to begin until the following month. During the latter part of September the preliminary work of definitely locating the lines of the proposed hurdles was done. Also there were erected a few portable buildings for the accommodation of laborers on the sand bar, or tow-head, lying to the east of the line of work.

On October 3 a large force of men with their quarters and a complete outfit of tools, &c., was transferred from Horsetail Bar, and the construction of the upper branch of the primary hurdle was begun at a point about 500 feet below the upper end, it

having been found impossible to drive piles between that point and the shore. The depth of sand was found not sufficient to hold them, the strong current running close to the bank having scoured the bottom almost to the bare rock.

Soon after starting the river began rising and covered the sand bar near the angle in the primary hurdle. In order that piles might be driven over that portion of the work which was exposed at low stages, the pile drivers were dropped down stream to the angle and began driving over the bar. The water continued to rise, and soon reached a stage over 29 feet on the Saint Louis gauge, causing such deep and strong currents down the Missouri shore as to render it impracticable to resume work at the head of the primary hurdle during the remainder of the season. The construction of a dike to make this shore connection was begun, however, but only one mattress, 24 by 40 feet by 100 feet, was placed before the field-work was entirely suspended.

The completed portion of the primary hurdle was thus left detached from the shore, and, in consequence, the silting-up behind the wall was not as great as it would have been had the connection been made, yet the water during the rise being very heavily charged with sediment, the deposit within the areas protected by the hurdle was in excess of any expectation.

Work for the season was practically suspended November 26, almost the entire force being then transferred to Twin Hollows, east side, and the equipment was placed in winter harbor.

The small force of men left was engaged in placing the mattress above referred to and in bracing piles until the middle of December, when they, too, were transferred to Twin Hollows, east side.

During the time of operations, piles were driven for 5,575 linear feet of primary hurdle and 250 linear feet of secondary hurdle. There were placed 1,400 linear feet of foot mattress in double widths, and 3,000 linear feet in a single width. Wattling was done on 2,375 linear feet of the primary hurdle for a depth of 14 feet.

On the accompanying tracing* the work done during this season is shown in black, that in red being the result of the work done between March and July, 1882.

An examination of the work showed that the portion of the primary hurdle lying above the angle had been somewhat damaged during the winter, most of the piles in the up-stream part, unprotected either by foot mattress or wattling, having been scoured out. A few were standing, but were so bent down that it became necessary to pull and redrive them. The lower part, or 600 feet immediately above the angle, was unwattled also, but protected from scour by a foot mat of single width. Here the piles were in good condition, only a few requiring to be straightened or redriven.

Below the angle 1,425 linear feet of hurdle was found entirely complete and uninjured. The remaining 875 linear feet was also in good order, though there remained a single width mattress to be sunk outside of it.

Field-work was resumed March 13, four pile drivers being set at work on that day to repair the line above the angle and to extend it up stream as far as possible. Other pile drivers were soon added to the force until ten were engaged. These drivers were placed at work at the lower end of the primary hurdle to carry it down stream and to extend the secondary hurdles to the Missouri shore as soon as the primary line had reached points of junction with them. Constructing and placing mattresses was also begun and pushed forward as rapidly as the pile-driving would permit.

The methods used in the construction of these hurdles were practically those in vogue last fall. Piles were driven from 12 to 14 feet into the sand in two rows, 18 feet apart, with the piles space 6 and 12 feet apart in the front and back rows, respectively. A mattress of two courses of brush laid at right angles was then constructed on a strong grillage lashed to these piles for support. These mattresses were built in sections about 100 by 25 feet, and as they were completed they were unlashed from the piles and sunk to the bottom with stone. In secondary hurdles the single width mattress sufficed, but in the primary line another width lapping about 5 feet over the first was built on the channel side of the hurdle and sunk. In very swift currents this mat was supported on a third row of piles 20 feet outside of the first row, with piles spaced 24 feet apart. When the currents were not so strong flats were used instead of the piles. The gunwales of these flats having been raised, enabling their use in swift water, this third row of piles will in the future be required only where extraordinary difficulty is encountered.

After the first fortnight wire was used, to the exclusion of hide-rope, for binding these mattresses, Nos. 12 and 14 being found so flexible as to be easily handled, and much more strong and enduring.

The wattling was done in the ordinary way, the brush being laid in courses and pushed down with hurdling forks by men working from small flats.

It has been customary to strengthen the piles in the wattled row by bolting each pile at the top to a longitudinal stringer, and this practice was followed wherever the work had to withstand strong currents or drift, but at other points the stringer was

* Tracing not forwarded.

omitted, it being thought that the wattling binding against the piles would furnish sufficient strength.

On the completion of the wattling the line was braced by booms notched and drift-bolted into the head of the piles in the front row and heeled against the bottom of the pile in the second row. After examination of old work and experiment in placing these braces it was found that the large ring-bolt, used to guide the lower end of the pile to its proper place, seldom succeeded in keeping it in front of the guide pile, the current usually pushing it to one side. This impaired the usefulness of the brace, as it allowed the braced pile to work to and fro in the current. These rings were consequently discarded, and a clevis or stirrup made of 1 inch round iron, such as is shown in the accompanying tracing, Plate VII, was used in its stead. The usual size of the clevis was about 20 inches in length by 12 inches in width, and with a bolt about 17 inches long. The end of this bolt was heated and bent down when placed in the pile to prevent its working out. These clevises have given satisfaction wherever used; for, as they can be made to fit very closely to the guide piles by boring the hole for the bolt wherever necessary, they prevent the braces from slipping aside.

There was no especial difficulty experienced in building the hurdles, except that the secondary lines could not be brought nearer than to within about 250 feet of the shore on account of the deep water and strong current which enters through the opening at the head of the work. This current has so scoured the bottom along the Missouri shore that within 150 to 200 feet of the water edge the depths of sand are insufficient to hold the piles. Especially was the effect of this current and the drift felt in building the secondary hurdle No. 1. This line was driven and washed out in places three or four times, and finally carried away altogether, although driven in clumps of piles and placed without wattling. It was intended to protect the front of this line with brush curtains, woven on wire, and a number were built for that purpose on temporary ways erected on small flats. Only one of them was placed, however, the rapid accumulation of drift preventing the use of the others at that time. Drift has carried away about 500 linear feet altogether from the other lines of hurdles, besides interfering greatly with the constructing and sinking of mattresses and with the wattling.

At the head of the work a persistent effort was made to connect the upper end of the primary hurdle with the shore and thus relieve the work below of the pressure of water which it was called upon to bear and which has prevented such a deposit from forming near shore as would otherwise have been gained. This gap, by keeping a force of men engaged there, scattered the work over an area extending $1\frac{1}{2}$ miles up and down stream, making it difficult to get from one point of the work to another quickly, and preventing a concentration of the force on any one part of the work.

At first it was thought that the gap could be closed by anchoring curtains or mattresses of brush on the line and buoying their tops, hoping in this way to secure a deposit behind them in which a line of piles could be driven reaching nearly to the shore. Of the ten curtains (each 100 by 24 feet) constructed, only two remained in place after launching, and these are near shore at the extreme upper end of the line. The others were launched in deeper and stronger water and each in turn was at once forced below the line and in to the shore. They were not lost, however, but were afterwards towed by the steamer A. A. Humphreys outside of the primary hurdle and placed against it. They were made fast to the piles and served instead of wattling.

It being thus impossible to use curtains for the purpose, it was decided to build floating sections of hurdles without wattling, and to sink them in place like cribs, and afterwards to drop curtains in front of them to check the water. Such a structure was begun on May 13.

As will be seen from the tracing, showing plan, section, and elevation, Plate VIII, it consisted of upright piles and their braces, bolted at the top and joined at the bottom by a pile bolted to each, and forming with them a rigid triangle. To a number of these triangles, placed 6 feet apart, a floor was bolted. This floor was made of piles laid on two sills and drift-bolted to them, and served to hold the stone with which to sink the crib. A front and back stringer of piles bolted to the uprights and braces, and a wall of pine lumber fastened to the uprights completed the structure. It was 244 feet in length by 20 feet in width by 30 feet in height. It was hung between four barges, and on June 16 was floated out from shore and sunk in place. While sinking, two of the anchor lines with which it was secured gave way, and the crib was bent in the arc of a circle and was sunk in that position. It has not moved since, nor shown any sign of weakness. This crib, built entirely of piles, proved very heavy and difficult to handle, and the plan was considerably modified in the two which were next begun. One of these (250 feet long by 30 feet wide by 30 feet high) was intended to complete the closing of the gap at the head of the works, and the other (200 by 30 by 20 feet) to make the shore connection in secondary hurdle No. 1.

In these the width of the floor is increased to 30 feet, and it is made of pine lumber 16 feet by 8 by 6 inches, drift-bolted to three sills, spaced 14 feet apart. The sills were made of piles scarfed and bolted together, and running the entire length of the crib. The triangles were made with a vertical height equal to the depth of water in

which they were to be sunk, and in order to distribute their weight more equally over the floors, were so made that the uprights and their braces made equal angles with the floor. To these triangles the floor is hung by stumps leading under the sill. The front wall was left off entirely, although the front and back stringers were retained. A stringer was also passed along the tops of the piles and secured to them with ring-bolts, so as to allow a little motion to the piles as the floor undulated in the waves. In the up-stream crib, in order to have the plane of the triangles when placed in the river coincident with the direction of the current, they were placed at an angle with the axis of the floor. This, as well as the general arrangement of the parts, may be seen in the accompanying tracing, showing a plan, section, and elevation of the crib, *Plato IX*. As the lower crib is intended to stand at right angles to the stream, the upright triangles were placed at right angles to the floor.

Thus far these cribs have fully justified expectations, being light enough to be supported on flats so that they may be readily handled. In building them, pile-drivers, with shears rigged at the leads, have been used to lift the triangles and piles into position and to raise the crib out of the water.

The early and long-continued high water was a source of great trouble throughout the entire season. From April 14 to July 1 the water surface was never more than 3 inches (and that for only four days) below the 20-foot level assumed as the height to which the work was to be brought; and it has been as high as 6 feet above it during the same time.

On account of this high water the force was reduced, June 1, in accordance with your verbal instructions, from about four hundred to one hundred men.

During the month of June no work was attempted save the construction of the cribs. This practically limited the working season to two and a half months.

During this time the primary hurdle was extended 7,000 feet, of which 2,650 feet were entirely completed. A single width mattress was sunk on 1,500 linear feet of the old work, and of this 650 feet was also wattled. Double width mat was sunk over 2,350 linear feet of the new work, which remains unwattled. On 1,500 linear feet the piles alone were driven.

It was originally intended to place the secondary hurdles every 400 feet, but it was afterwards decided to increase this distance to 2,000 feet, and that the new No. 1 should be built on the line originally intended for No. 6. Only four of these hurdles were begun. Of these, 1,800 linear feet (Nos. 3 and 4) were entirely completed and the piles and mattress were placed for 1,600 linear feet more (Nos. 1 and 2.) Altogether there were wattled 4,100 linear feet of hurdle, averaging 10 feet in depth. In addition there were made and sunk 1,040 linear feet of brush curtains, averaging 25 feet in width, and there were woven on wire 360 linear feet of curtains 22 feet in width.

One crib was constructed and sunk and two others were partially completed.

In closing, I desire to express my thanks to Messrs. J. L. Duffy, Sidney B. Cady, and J. W. Irwin, assistant engineers, for the valuable assistance given by them in the prosecution of the work.

Very respectfully, your obedient servant,

WM. S. MITCHELL,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

E.

CARROLL'S ISLAND.

REPORT OF MR. C. V. MERSEREAU, ASSISTANT ENGINEER.

TWIN HOLLOW, EAST SIDE, July 19, 1882.

SIR: I have the honor to submit to you the following report of operations at Carroll's Island for the year ending June 30, 1882.

PROTECTION OF CARROLL'S ISLAND.

The protection of the lower part of the west bank of Carroll's Island was formerly considered a necessity in connection with the improvement at Horseshoe Bar, but when the flood of last spring had subsided, erosion of the bank had ceased. A sand-bar having extended from the head of the island to some distance below the point where it had been most active, the necessity seemed to exist no longer, but later active erosion began on the bank below, and, working up stream as the water fell, reached a distance of about $\frac{1}{4}$ of a mile above the foot of the island, about the middle of September.

The activity of this erosion was such that the necessity of protecting the bank soon

became evident, and that work was begun October 3, at the upper point named, by the method designed for that purpose as shown in drawings* furnished with your verbal instructions, consisting of a mattress 120 feet wide to protect that portion of the bank below the plane of ordinary low-water; a revetment of stone between that and the 20-foot stage, using loose brush mats to cover the surface of any portion of that zone which happened to be under water at the time that any revetment should be constructed; and plantations of willows from that stage to the top of the bank, grading the bank to a regular slope before planting the willows.

A line of guide piles spaced 15 feet between centers was driven as nearly as practicable 15 feet inshore from the curve of standard low-water, following the general alignment of the bank; and guided by this line the mattress was constructed upon floating ways.

The length under process of construction at any one time was about 25 feet, which was the available width of the barge upon which the ways were floated, and also about the length of poles used.

The poles were about 6 inches in diameter and were made continuous by splicing them together, for which purpose two consecutive poles were lapped about 4 feet, and were well fastened with wire and spikes. The brush was from 2½ to 4 inches in diameter and 30 to 35 feet in length, wattled upon the poles by passing a rod of it alternately above and below them.

The rods used in wattling to make a course in the mattress were lapped about 6 feet, but each was left detached. The butts of the rods at the edges of the mattress were turned outward and about every fifth rod on top or every tenth one of the whole was nailed to the poles at each edge of the mattress.

One mattress was built during the season, which was found to be 1,695 feet long when completed. That the length is greater than was originally intended may be due to circumstances which prevented the floating of it until 1,000 feet could be finished.

On account of the drift-wood under the head, sections on the upper end had to be placed when only about 700 feet had been constructed, and in order to complete the section to the original length, a part only was sunk, leaving enough afloat to keep the connection unbroken. Afterwards the sinking followed the construction, about 200 linear feet being left afloat, until the whole was launched and sunk at the lower point of the island.

This experience indicates that mattresses can be continued and successfully placed in sections of any desired length under ordinary circumstances of weather, drift-wood, velocities, and direction of currents during an entire working season.

The placing of the first section so that its inner edge would coincide with the curve of standard low water was an interesting subject of study; this required that the mattress should sink vertically, neither dropping down stream nor being hauled up stream during the process. That was accomplished by attaching lines to its head, long enough to keep the up-stream end of the mattress practically in the same vertical plane while passing from the surface to the bottom, passing them under the barge, and making them fast to suitable moorings on shore as a preliminary step toward sinking; but, before beginning that work, strains were brought upon these lines by means of a Spanish windlass, heaving them so taut that no slack was perceptible. The tensile strain on all the lines is measured by the resistance that the sinking mattress offers to the free flow of the water. This could not be exactly determined, the data required for such calculations being unknown and scarcely attainable.

The experiment proves, however, that mattresses can be successfully placed with an edge coinciding with a given line and in long sections, or continuous, at nearly if not quite all localities on this section of the river requiring protection. The depth was not great, and the velocity of the current at the stages prevailing while the mattress was under process of construction was less than would be found at most of the points requiring protection on account of the volume of water which flowed through the passage east of the island with a greater velocity than that of the main channel, checking the velocity on the west side of the island farther up stream than the head of the work.

The experiment was purposely tried in the comparatively slack water, taking all the precautions that would be necessary in swifter currents to train the overseer and others in the details of the work preparatory to making the more severe test of sinking the mattress upon the bank below, where both depths and velocity are great, while the direction of the current sets across the mattress, forming conditions no more favorable than would be found at a large majority of caving banks. About half of the mattress was placed on a bar not less than 18 feet above low water, where the bottom was from 7 to 10 feet below that plane when the work was begun.

As a broad, high bar formed outside of the island during the decline after the November flood, work above the plane of standard low water, including the revetment,

* See Plate XIV.

grading, and planting of willows, was unnecessary at that time, and that part of the protection was left to await future developments. The work was completed on December 10, 1881, and the force transferred to Twin Hollows, east side.

During the season 1,695 linear feet of mattress 120 feet wide were constructed and placed, in the construction of which 1,467.9 cords of brush, 600 cubic yards of stone, and miscellaneous material to the value of \$898.35 were expended.

The value of bank protection either as a means of improving or preserving a channel often depends upon the rate at which it can be completed, and for that, among other reasons, an effort was made to determine the maximum rate at which such mattresses could be constructed consistent with economy in cost. Unfavorable circumstances conspired to prevent satisfactory conclusions being reached. During a great part of the season heavy rains fell almost daily, the river was high and rising, large masses of drift accumulated under the mattress, and laborers were continually changing, few remaining long enough to become expert in construction, most of them moving farther south as fast as they came into possession of sufficient funds. Under such conditions a fair test could not be made, and the maximum rate obtained cannot be considered as an overestimate of that which can be accomplished under favorable circumstances. When working a full force 100 linear feet per day were constructed and launched, which amount may be increased as the workmen have become expert.

The sketch forwarded herewith, Plate X, shows the location of the work.

Very respectfully, your obedient servant,

C. V. MERSEREAU,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

F.

TWIN HOLLOWES, EAST BANK.

REPORT OF MR. C. V. MERSEREAU, ASSISTANT ENGINEER.

TWIN HOLLOWES, EAST SIDE,
July 13, 1882.

SIR: I have the honor to submit to you the following report of operations at Twin Hollows, east side, for the year ending June 30, 1882:

PROTECTION OF TWIN HOLLOWES, EAST SIDE.

The work of protecting the bank at Twin Hollows, east side, was begun on October 26, 1881, by a force of men transferred from the works at Carroll's Island.

The method employed was that designed for the purpose.* It consists of three parts: a low water mattress 120 feet wide, the shore edge of which is placed on the line of standard low water; a revetment extending from the edge of the mattress to 16 feet above standard low water; grading of the bank to a uniform slope of 2 to 1 and planting with willows.

The low water mattress, 120 feet wide, was constructed by wattling brush upon from 22 to 30 weaving poles. The number of poles depended on the size of the brush furnished, the short light brush requiring more poles than the larger and thicker brush. The poles were made continuous by being lapped about 4 feet, spiked and wired. Their ends at the head of the mattress were secured by being treenailed to a heavy cross-piece by $1\frac{1}{2}$ inch pins.

In the construction the poles were evenly distributed over the ways, and the upper ends secured to the cross piece. The down-stream ends were cut off even with the ends of the ways. The brush was then wattled on the poles by passing a rod of it alternately above and below them. The brush was wattled on the down-stream end of the poles, then slipped down and made tight by the use of large wooden mauls. The brush used to make a course was lapped about 6 feet, but was left detached. The butts of the brush were turned outwards, and every tenth one nailed to the poles at the edges of the mattress. The brush was wattled on the poles to within about 4 feet of their ends. The barge carrying the ways was then dropped down stream sufficiently to allow the portion of the mattress already constructed to be drawn to the lower ends of the ways. New poles were then spliced on to those in the portion just launched and the wattling continued. The amount of mattress under construction at any one time was from 20 to 30 feet, the latter being the available width of the mattress barge.

* See Plate XIV.

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The size of the poles ranged from 2 to 5 inches at their small ends and from 5 to 9 inches at their larger ends. The brush was from 20 to 40 feet long and from 1½ inches to 4 inches in diameter.

Work on the mattress was begun on October 26, and pushed forward till December 10, when, all of the brush having been used from the Illinois shore, the mattress was launched from the ways and placed. The entire length of this mattress was 1,245 feet. It was woven continuous, and no trouble was found in making it conform to the general contour of the bank, although there were several short, sharp bends.

The storm of November 19 and 20 drove the mooring barge hard aground and swung 150 feet of the upper end of the mattress in over the guide piles. When placed the inner edge was in contact with the bank at the water surface instead of at the line of standard low water. This portion was made to form part of the revetment mat. No trouble was experienced in sinking this portion of the mattress.

The mattress work was resumed on December 17, the brush being cut for the purpose on Carroll's Island, and 248 linear feet constructed before the work was discontinued on account of unfavorable weather. In sinking this small section a piece 75 by 35 feet broke off from and was doubled under the outer edge, by the strong current. By loading the mattress in the middle the broken portion was brought to the surface and afterwards sunk in its proper position.

Work was discontinued on January 8, 1882, on account of unfavorable weather.

During the season 690 linear feet of loose brush mat for revetment, averaging 40 feet wide, was constructed and placed.

The work of last season was inspected on March 7 by Mr. J. O. Holman, who had been appointed resident engineer, and found in good condition. During the following week a kitchen crew and part of the outfit arrived, and the quarters were put in good condition. The low water mattress was begun on March 21, and has been continued up to the present writing, with but few interruptions. It was commenced at station 14 + 80 and made continuous to station 53. On April 4, the first 400 feet sunk easily and in good condition. The inclined portion was held in position by two small flats. The storm of the following week sunk one of the flats and broke a piece about 30 feet by 50 feet from the outer edge of the mattress. Considerable difficulty was experienced sinking the next 800 feet (station 20-station 28). The current was strong and the water from 36 to 40 feet deep on the outer edge of the mattress. Extra bracing was put on after each sink, still the outer edge was broken more or less between these points. None of the breaks extended, however, over 50 feet in from the outer edge, and they would probably average about 35 feet.

On April 16 the sinking from station 28 to station 33 was successful.

The sinking from station 34 to station 39 was attempted April 27. Two mooring barges were used, the upper one at station 34 and the lower one at station 39. Lines were made fast to the mattress above and below the barges so as to give as long a slope as possible between the sunken and floating portions. The rock barge was placed just below the upper mooring barge. The mattress was sinking in good condition when the lines by which the barge was held parted, and the barge swung against the mattress. The pressure with the inshore current pushed the mattress in against the piling and doubled the outer edge under to station 39, where it was held by the lower mooring barge. At station 39 the mattress tore about two-thirds across. This portion was afterwards examined by a diver, who reported it about 70 to 85 feet wide. From station 39 to station 45 the mattress was sunk in good condition. The inclined portion below station 45 was held in position by barrels. On May 12 an attempt was made to sink the mattress from station 45 to station 51, at which point the inclined portion was to be held in position by three rows of barrels. The current was very strong and struck the mattress obliquely between station 45 and station 51. The mattress parted at station 48, and it was wrecked as far as the mattress barge at station 53. It also carried away six of the ways from the barge. The wrecked portion was loaded and sunk. It probably covered a width of about 80 feet.

On May 16 the mattress barge was taken back to station 46 and a new mattress begun with a grillage of poles beneath.

The section extending from station 46 to station 59 + 25 was sunk on June 12. The method of placing was as follows: A line of barges was dropped along the outer edge of the mattress. They were held in position by a head-line leading up to the shore and two anchors to each barge placed quartering out and up the stream. Lines from the barges were made fast to the mattress, part of them passing under the barges. Sufficient strain was then put on the anchor-lines to hold the mattress out from the piling and to prevent it sagging down stream. Two barges partly loaded with stone were then hauled over the mattress near station 53 and the stone from one of them evenly distributed over the mattress as it was hauled up. In this partial loading care was taken not to load the mattress more than the lines from the barges would hold. The partial loading sunk the mattress from 2 to 7 feet below the surface of the water, and extended from station 46 to station 53. The second partially loaded barge of stone was placed across the mattress just below the mooring barge, and a barge fully loaded

placed across at station 53. The head of the mattress being held from the mooring barge was then heavily loaded and lowered into position. The line leading under the mooring barge and up shore from the head of the mattress prevented it from sagging down stream. The lines from the barges were paid out gradually as a heavy strain came on them. The upper portion of the mattress went down without a break in it. While the head was being lowered the barge at station 53 was being dropped down over the mattress, loading it as it went. Through mismanagement of the barge a break occurred at station 55, and the outer edge was more or less folded for about 100 feet. Between station 56 and the end of the mattress (station 59 + 25) it went down in good condition. A new section of mattress was immediately begun, and its construction is still being pushed forward. The grillage of poles was dropped after the first 200 feet. On June 30, 964 linear feet had been constructed.

The revetment had been extended from station 11 + 50 to station 22, and from station 48 to station 49 + 50. The loose brush mattress under the revetment was discontinued below station 11 + 50 and stone alone used.

Eight hundred linear feet of shore mattress, averaging 75 feet wide, were put in. That placed from station 14 + 50 to station 17 was to bring the mattress work into low-water. Between station 33 and station 37 and stations 48 — 49 + 50 it was put in to stop caving of the bank.

The bank between stations 0 and 21 was graded by the use of the hydraulic excavator. The ground was full of brush and stumps, making it difficult to grade. The average rate of grading was about 100 linear feet per day. High-water has prevented the continuation of the grading.

Five small hurdles were constructed for the breaking up of eddies. They are located at stations 14 + 50, 17, 34, 35, and 43.

The current appears to have followed the mattress barge as it was moved down stream, and formed an eddy 200 or 300 feet beyond it.

The bank has caved very rapidly in some places as the mattress approached it. However, but little caving has taken place after the mattress has been placed.

The sketch forwarded herewith, Plate XI, shows the condition of the work on June 30. The red line shows the location of the shore line on March 27. That in black is the present shore line. The soundings are those taken in May, excepting those along the mattress, which were taken as the mattress was constructed.

During the year there have been constructed 7,564 linear feet of low water mattress, 5,900 feet of which have been placed, 964 feet are ready for placing, and 700 feet wrecked, but on the bottom, in which were expended 4,621.89 cords of brush, 2,112.36 cubic yards of stone, 552 piles, and miscellaneous material to the amount of \$1,766.51 (miscellaneous material); 1,950 linear feet of shore mattress, averaging 50 feet wide, in which were expended 1,176.81 cords of brush, 184.11 cubic yards of stone, and miscellaneous material to the amount of \$97.05 (miscellaneous material); 1,500 linear feet of riprap, in which were expended 709.64 cubic yards of stone.

Very respectfully, your obedient servant,

C. V. MERSEREAU,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

G.

BEARD'S ISLAND.

REPORT OF MR. J. W. RECORD, ASSISTANT ENGINEER.

BEARD'S ISLAND, ILL., July 17, 1882.

SIR: I have the honor to submit herewith the following report of operations at Beard's Island for the year ending June 30, 1882:

I first arrived on the ground on March 17. The island at that time was being cut away at its west bank from a point about 2,000 feet below the head of the island to the extreme lower end. For 2,000 feet below the head of the island there was very little waste. At the first opportunity I made a survey of the west bank of the island, and established a line, with stations every 100 feet, to refer the work to.

This survey showed that the island had been cut away at places more than 800 feet since the survey was made in 1880, and an average width of nearly 600 feet the entire length of the island. The channel of the river was inside the position of the old shore line for nearly the whole length of the island. The current was not very strong along the bank above station 20, except for a distance of about 200 feet at the head of the

island, where it was very strong, and its direction inclined nearly 90° to the shore line.

Below station 20 the current was very strong, and its direction also inclined to the shore line.

The works at this place have been the construction of a bank protection and a hurdle about 1,000 feet long to close a chute at the head of the island. The bank protection consisted of a continuous mattress 120 feet wide,* that extends up to the standard low water line, and a stone revetment that extends 16 feet above this line.

There were delays in getting the pile-driver started which delayed operations several days, and the construction of the mattress was not begun until the last day of March. Progress was quite slow at first, the average amount constructed per day for the first week being only 54 feet; but the rate increased each week as the foreman and laborers learned to apply their labor to a greater advantage, until it reached 108½ feet per day for the week ending May 13. The largest amount constructed in any one day was 130 feet. The mattress construction was continued until 1,100 feet were completed, when 900 feet of it were sunk. Sinking the mattress has been the most difficult part of the work at this place. The first 900 feet were sunk without special difficulty, the current being feeble and the water shallow. The barge of stone was drawn up to the mooring barge and stone thrown on the outside corner of the mattress. It was then allowed to sink, by means of dropping lines fastened to the mooring barge, just enough to let the stone barge pass over it. Stone was then thrown over the mattress and the end allowed to sink to the bottom. As the barge drifted down broadside across the mattress enough stone was thrown on to sink it. This method of sinking did very well in a gentle current and where the water was not very deep, but where the water was deep and the current strong it was found that it would be necessary to buoy it up at the outside by means of barges anchored in the stream, and not leave it free to the action of the current.

During the month of April 1,600 feet of mattress were constructed and some 1,300 feet sunk. After the first 900 feet were sunk shorter sections of 300 or 400 feet would be sunk at a time, at intervals of three or four days, until 2,000 feet had been sunk.

From station 16 to station 30 the shore line bends through an angle of some 25°. The current was strong and its direction inclined to the bank. For these reasons it was thought best not to sink short sections at a time and leave it to the action of the current in the bends, but to let it lie on the surface of the water until enough had been constructed so as to be able to sink through the worst place all at once. On May 19 the mattress was completed to station 33, of which 1,300 feet were still on the surface of the water. It was intended to sink 1,000 feet of this May 20, but all the stone on hand was expended in sinking 600 feet. This left the mattress in a very bad condition. That part of the mattress between the bottom and the surface of the water came opposite a sharp curve in the mattress. The current was strong and its direction inclined to the bank. The sinking was done Saturday afternoon, and no more stone could be procured before Monday. The mattress held together until the evening of the next day, when it broke. It was made secure as soon as possible by fastening two lines at the outer edge, but before this could be done it got badly skewed; the outer edge moving down stream, while the shore side was held by the yokes. On the next day an effort was made to sink the broken section, but it was so badly skewed that it broke several times while sinking. It all sunk, but in a very bad condition.

A mooring barge was then set at station 32 + 50. Only 380 feet, however, had been constructed when the mooring lines broke and let the end of the mooring barge swing down stream, which crowded the ways barge against the guide piles so hard that the mattress could not be continued. It was launched from the ways barge and sunk. An enormous amount of drift had collected under the mooring and filled the entire space between the barge and the river bed for one-half the length of the barge, forming a kind of "rack-heap," which remains there to-day. During the month of May 2,000 feet of mattress were constructed. I then had orders to construct a short section of mattress to repair the broken place in the mattress first constructed. It was known that it broke at the shore edge at station 26. A careful examination was made at the outer edge, but the water being 40 feet deep it was impossible to determine much in regard to its condition. I had the mooring barge set at station 25 so as to be reasonably certain the mattress would cover the gap. Three hundred feet were constructed at this place. It was finished June 14, and sunk June 16. The velocity of the current had diminished a great deal here since the first mattress was sunk, and it was not necessary to use a mooring barge alongside while sinking.

A mattress was then started at station 35 + 50. It progressed very slowly; the high-water and the great amount of drift rendering its construction extremely difficult, so that on June 30 only 640 feet had been constructed.

None of the stone revetment was laid until May 18, and then only for a short distance at the head of the island. It was afterwards continued as fast as the stone could

* See Plate XIV.

be obtained, and on June 30 was completed as far as station 16 + 50, with the exception of two small sections.

April 26 I received orders to construct a hurdle to close the chute at the head of the island. A pile-driver was immediately set at work driving the piles. On May 31 all the piles were driven and a foot-mat 450 long constructed and sunk. The high-water then stopped operations for several days, and washed out the piles for a distance of 150 feet. As soon as the water fell below the tops of the piles the wattling was commenced. The sediment drifted in and deposited nearly as fast as the wattling was completed, and the work was pushed as fast as possible in order to obtain the benefit of the high-water. It was completed June 29, and at that time a deposit had formed nearly to the top of the piles.

On the accompanying map* figures in red indicate soundings taken March 31; figures in black those taken June 30; the former soundings raised to the stage of water of the latter.

Before closing I will express my thanks to Mr. J. E. Savage, assistant engineer, for his intelligent assistance and the interest he has shown in the work.

Very respectfully, your obedient servant,

J. W. RECORD,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

II.

"JIM SMITH'S."

REPORT OF MR. JOHN O. HOLMAN, ASSISTANT ENGINEER.

JIM SMITH'S, ILL., July 11, 1882.

SIR: I have the honor to submit the following report of the preparatory work of May, and the construction work of June, comprising all that has been performed at Jim Smith's during the fiscal year ending June 30, 1882.

Four portable buildings, to be used as office and quarters, were in process of erection from May 23 to May 27. Two pile-drivers, on the 29th, 30th, and 31st, drove a number of piles for mooring barges to be used during the construction of secondary hurdles at the upper end of work.

On June 1 the initial point was changed, being moved up stream 3,800 feet.

The construction work has all been on the primary hurdle line, beginning at the upper end, and during the month of June there was made 850 feet of foot-matress, of which 800 feet was sunk into place; 500 feet of wattling on primary hurdle line, varying from 2 feet to 22 feet in height, and 250 feet of hurdle matress 10 feet in width; 426 piles were driven.

The tracing of the progress map, forwarded with this report,† shows, in addition to the primary hurdle line and the completed work, the projected cross hurdle lines.

The line FE was the primary hurdle line as originally given, but this was extended to F' on June 1. The line F'FE is 17,125 feet long. The secondary hurdle lines, numbered on the tracing from 1 to 9, vary in length from 800 to 1,950, and have a total length of 11,350 feet. The shore lines are from survey made June 26 to June 28, inclusive. The dotted shore lines from survey of 1831 show the bank receded 750 feet at secondary hurdle No. 8, and 300 feet at secondary hurdle No. 3. The soundings were taken from a yawl June 29 and 30.

The cross lines on FF'' are 100-foot stations. On the tracing the heavy line to station 15, the line to station 9, and the line to 8 + 50 represent, respectively, the drift row, the hurdle row, and the bracing row, and the length to which they were extended from F' by the driving done during June.

A stringer has been placed on the entire length of the drift row, secured to the piling by large screw bolts. The depth of water and strong current made it necessary to use these in order to keep the piles from working loose. The hurdle line has been secured with stringers immediately after driving, and during the high water the braces have been placed and fastened to the hurdle row after the foot-matress is sunk, and before the wattling is done. This will not retard the wattling materially, for the time lost in passing brush around the piles in the hurdle row and under the stringers has been regained by more rapid work due to steadiness of the piles in the hurdle row.

*Large scale map not forwarded. Location of work shown on Plate XII.

†Large scale map not forwarded. Location of work shown on Plate VI.

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The hurdle line is wattled to station 5, dropping in height from a 27-foot stage at the bank to a 22-foot stage at station 5. The wattled curtain was placed from station 5 to 7 + 50. It was built in 85-foot lengths, and was used where the water was too deep to allow of wattling with the forks now in use. These wattled curtains were constructed in the following manner: Poles of about 35 feet in length were placed across the piles, one just ahead of each hurdling pile and resting on the stringers of the hurdle and drift rows, being secured by rope lashings to the hurdle stringers. That portion of the poles between the hurdle and drift rows was then woven with brush to a distance of 10 feet from the drift piles, the men working from flats while weaving. Fastenings were made with wire to hold the edge of the curtains securely to the poles. A sketch has been made, and is forwarded with this report, showing the plan, elevation, and section of the wattled curtain, Plate XIII. In the plan a portion of curtain is shown just before launching from the stringers of the drift row. The weaving-poles are lashed to the stringers of the hurdle row and an anchor-line is fastened from the wattled end of the upper weaving-poles to a hurdle pile about 100 feet up stream. Large stones are wired to the upstream end of the curtain, which after being swung against the hurdle row by the current will sink to the foot-matress. The dotted lines in the section *a c* give the position after swinging against the hurdle row. In sinking to the foot-matress the lines are slackened so that the poles will rest against the piles, as shown in the elevation. A spike in the end of the weaving-poles holds the curtain in place until the wattling, which, as shown by the elevation and section, embraces the pole and pile, thus effectually securing the wattled curtain in place.

From 2, on the 1st of June, the number of pile-drivers was increased to 7 on the 14th. They were in continuous use driving, with the exception of No. 1, which was used in placing the braces on the brace row of piles. A brace was placed at each brace pile, secured to it by a clevis, the upper end of the brace being notched into and bolted to the hurdle pile. The braces are not quite in line with the current, but make an angle of about 45° with the brace line.

Two sets of quarters on barges, and one set on shore, have been in constant use. An additional set was erected on shore at the upper end of the works, but was not in service during June.

I remain, very respectfully, your obedient servant,

JOHN O. HOLMAN,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

I.

ENGINEER DEPOT.

REPORT OF MR. C. L. STEVENSON, CLERK.

UNITED STATES ENGINEER DEPOT,
Saint Louis, Mo., July 7, 1882.

SIR: Agreeably to paragraph 88 of the regulations for 1882, I have the honor respectfully to submit a condensed report of the operations at the Engineer Depot for the fiscal year ending June 30, 1882.

The equipment was increased during the year by the construction of eleven pile-drivers, numbered from 11 to 21, inclusive; one hydraulic excavator, numbered 1; two mattress barges, numbered 2 and 3, respectively; thirty-seven portable shanties for quarters; eighty flat-boats; twenty-nine coal-barges, of which twenty-seven were on hand at the beginning of the year, and two purchased since were altered for barge-flats.

The pile-drivers were built of same general design as those described in previous reports, except that the water supply for pumps on those numbered from 17 to 21, inclusive, was increased by enlarging the surface of the strainer from 19 to 50 square inches.

No. 11 was completed and put into service about the middle, and Nos. 12 and 13 the last, of July; Nos. 14, 15, and 16 completed in August; 18, the last of November; and 19 and 21 finished in December.

The hull of excavator No. 1 is of the same model and dimensions as those for pile-drivers, with the addition of a guard 2 feet wide on each side. The cabin is 20 feet broad, 48 feet long, 11 feet high. It is equipped with a Worthington compound duplex steam-pump, having two 12-inch and two 18-inch cylinders connected with two cast-

iron shoes by a 7-inch copper pipe. The discharge—about 700 gallons per minute—passes first through a 6-inch pipe, then through a Y-shaped pipe, the two arms being $4\frac{1}{2}$ inches each in diameter, and, connected with a hose of same size, is delivered through two nozzles, each 2 inches in diameter.

The excavator—commenced about 1st of August—was completed October 20.

The mattress barges are 150 feet long over all, 8 feet rake, 28 feet wide, and 5 feet gunwale depth. A bulkhead runs fore and aft, resting on an 8 by 10 inch keelson, with fore and aft strokes on each side of the bulkheads, having stanchions under the middle streaks, and the beams and decks of substantial material.

Way pieces of oak, 3 by 8 inches, arranged for building a mattress 120 feet wide, extend over one side 15 feet. These barges were commenced August 27, and completed—No. 2 on the 1st and No. 3 on the 20th of October.

The flats are:

24, 6 feet broad, 20 feet long, 12 inches deep.

26, 9 feet broad, 30 feet long, 16 inches deep.

30, $9\frac{1}{2}$ feet broad, 35 feet long, 22 inches deep.

Sixteen of the twenty-six were subsequently altered by adding to the top of the gunwales 6 inches, making them 22 inches deep.

The small flats are used for caulking barges, bracing hurdles, and other light work, and the larger ones for general use in connection with the construction of hurdles.

The portable shanties for quarters number as follows, viz: Twelve mess-rooms and kitchens, each 20 feet broad by 60 feet long; fourteen sleeping-rooms, each 20 feet broad by 45 feet long; four foremen's quarters, each 20 feet broad by 15 feet long; three foremen's quarters, each 20 feet broad by 30 feet long; four offices and quarters, each 16 feet broad by 32 feet long; the latter for assistant engineers. Each set of quarters is furnished with a proper complement of such bunks, tables, benches, wash-stands, closets, mess furniture, and cooking utensils as are necessary for the service for which such quarters are respectively intended.

The portable shanties (designated by letters)—are similar to those built last year, which are fully described in the last annual report.

The coal-barges were purchased to be altered for carrying material and for other service connected with the work on the improvement of the river. They are about 134 feet long, 24 feet broad, and $7\frac{1}{2}$ feet hold, and are numbered from 28 to 56, inclusive. They were strengthened by placing new stiffeners and side clamps the whole length, most of them with two new fore and aft bulkheads, new deck frames, decks, capstans, pumps, timber-heads, &c.

Slight repairs were made to flat barges Nos. 31, 33, 36, 46, and 48.

Barges Nos. 12, 13, 14, 17, 18, 19, and 20 were overhauled and thoroughly repaired, most of them receiving new deck frames, decks, timber-heads, and other substantial repairs.

A new hull was built for pile-driver No. 2, of same dimensions as those previously made; a new crab placed on pile-driver No. 5; new brace to leaders of pile-driver No. 3; ways were extended and other repairs made to mattress barges Nos. 2 and 3.

Repairs were made to steamers Humphreys, Anita, and steam launch Hornet. To the former guards and nosing on both sides from bow to engine-room, plank sheaves, kevels, fenders, stern bulkheads, chocks, deck to the after end of coal-room, and four boiler-deck stanchions were renewed; capstan, railing on both sides, and other general repairs were made. There were added also a bracket-boom, foundation, and other necessary arrangements for an electric light on the boat. The main and boiler decks of the Anita were repaired, some of it relaid and renewed, the nosing, plank sheaves, chocks, stock-knees, bits, cups, kevel, and some short hoods renewed, and other general repairs made. The steam launch Hornet was drawn out of water, overhauled, thoroughly repaired, and painted; new cylinder timbers, two strainers to supply pipes, and other additions made.

Preparations for an engineer depot on the ground in front of the old arsenal south of Arsenal street began on the 21st of January by leveling the irregularities in the ground. A portion of the old arsenal wall was removed so as to construct a roadway to a landing. Two rows of piles driven for a hurdle line, which was partly completed, a distance of about 135 feet from the wall into the river, were used to construct a roadway for shipping purposes, the way being 18 feet broad, extending to a platform at the end of it about 20 by 26 feet.

The buildings which have been erected here are: one office, 16 by 32 feet, with 8 feet ceiling, which is divided into two rooms of equal size and used as offices for the material and subsistence departments, respectively; one warehouse, 125 by 25 feet, 13 feet ceiling, used for storing material; one warehouse of same dimensions as the last, used for subsistence stores. Under this house is a cellar full size of the building, ceiling $6\frac{1}{2}$ feet in the clear, with solid stone walls, plank floor, and properly drained by pipes leading to the river. One house, 20 by 40 feet, 8 feet ceiling, used as carpenter shop; one house, 20 by 50 feet, 8 feet ceiling, for blacksmith shop, arranged for six forges; one house, 16 by 70 feet, 8 feet ceiling, for oakum-room.

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The blacksmith shop and oakum house were reconstructed mainly of material removed from the buildings used for same purposes at Marine avenue. One house, 16 by 20 feet, 8 feet ceiling, for oil-room and paintshop. All of these buildings are substantially made, of good material, shingle roofs, and proper complement of glazed windows. The rooms for offices are weathered and ceiled.

All implements, tools, appliances, repairs, alterations, and other work of like description needed from time to time by the several engineer and other parties connected with the works immediately below Saint Louis, which requisitions in the aggregate amount to a considerable number, have been filled here.

The material for building new hulls to pile-drivers Nos. 3 and 5 has been framed and prepared to be put together, but further work thereon has necessarily ceased, recently, on account of the extraordinary high water in the river.

With much respect, your obedient servant,

C. L. STEVENSON,
Clerk.

Maj. O. H. ERNST,
Corps of Engineers.

K.—Record of gauge at Grafton, Ill., for the fiscal year ending June 30, 1882.

[Height of water above a plane 200 feet below the Saint Louis City directrix.]

Day.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1	206.60	200.80	195.36	202.22	212.00	208.48	203.50	198.10	201.50	204.96	211.00	211.10
2	08.60	00.55	95.30	02.80	12.35	07.50	02.85	98.28	01.92	95.00	10.90	11.28
3	00.66	00.25	95.32	03.85	12.50	07.00	02.40	98.10	01.76	05.10	10.70	11.65
4	00.70	199.95	05.40	05.30	12.65	06.55	02.15	98.00	01.84	05.35	10.45	11.80
5	00.60	99.50	95.45	06.40	12.80	06.00	01.80	98.60	02.00	05.40	10.60	11.80
6	06.00	99.15	95.50	06.70	12.87	05.00	01.50	98.45	02.32	05.35	09.40	11.84
7	05.30	98.00	95.60	06.75	12.89	05.20	01.15	98.45	02.65	05.35	08.30	11.88
8	04.15	98.22	95.82	06.74	12.90	04.85	00.85	98.52	02.78	05.14	08.35	11.88
9	03.30	97.80	96.00	07.20	12.80	04.60	00.90	98.60	03.10	05.40	10.15	11.68
10	02.64	97.50	96.30	07.30	12.70	04.45	00.82	98.70	04.00	05.35	10.20	11.35
11	01.80	97.20	96.65	07.00	12.45	04.00	00.70	98.52	04.95	05.64	10.90	11.00
12	01.34	97.00	97.00	06.80	12.50	03.90	00.55	98.30	05.44	05.90	11.22	10.45
13	01.60	96.70	97.16	06.75	12.50	03.88	00.45	98.38	05.20	06.20	11.22	10.25
14	02.85	96.40	97.38	06.84	12.50	05.00	00.45	98.44	04.80	06.60	11.22	10.25
15	03.50	96.25	97.56	06.95	12.55	05.00	00.45	98.46	04.52	06.95	11.10	10.40
16	04.50	96.15	97.70	07.10	12.50	04.50	199.80	98.30	04.20	07.20	10.02	10.65
17	05.20	96.00	97.92	07.00	12.36	04.40	99.40	98.74	04.15	07.35	10.80	11.10
18	05.80	95.90	98.10	08.10	12.80	04.00	99.00	98.90	04.05	07.68	10.42	11.55
19	06.30	95.85	98.22	08.75	13.50	03.70	98.70	99.10	04.05	07.60	10.50	11.46
20	06.75	95.82	98.45	09.20	13.94	03.42	98.54	204.34	04.25	07.00	10.18	11.05
21	07.20	95.90	98.55	09.70	13.78	03.22	98.15	98.50	04.40	06.90	09.80	10.70
22	07.65	95.90	98.70	10.20	13.25	03.50	97.85	99.50	04.90	07.15	08.35	10.50
23	07.75	95.02	99.00	10.60	12.60	03.95	97.70	99.02	05.04	08.10	08.70	10.16
24	07.64	95.00	99.10	10.85	11.90	04.20	97.80	99.00	05.04	08.94	07.90	09.92
25	07.05	95.85	99.55	10.95	11.20	04.20	98.10	04.52	05.00	09.40	07.75	09.50
26	06.00	95.74	99.85	11.20	10.00	04.00	98.10	02.74	04.90	10.00	06.85	09.18
27	04.50	95.74	200.16	11.40	10.02	03.95	98.10	01.60	04.94	10.45	06.90	09.48
28	02.85	95.62	00.40	11.55	09.48	03.95	98.10	01.10	04.80	10.60	08.00	09.99
29	01.90	95.62	00.75	11.70	08.95	03.80	97.90	.....	04.85	10.95	09.12	10.53
30	01.36	95.50	01.50	11.85	08.48	03.80	97.75	.....	04.90	11.05	09.75	11.36
31	01.00	95.40	.....	11.90	.....	03.80	98.05	.....	04.95	.....	10.40	.....

L.—Record of gauge at Alton, Ill., for the fiscal year ending June 30, 1882.

[Height of water above a plane 200 feet below the Saint Louis City directrix.]

Day.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1	199.85	193.87	188.32	194.30	203.42	200.15	195.62	190.60	195.35	197.05	203.43	205.22
2	200.65	93.60	88.25	95.45	93.08	199.75	95.10	90.62	95.62	97.20	93.25	95.62
3	01.23	93.30	88.28	96.00	93.80	98.82	94.65	90.40	94.87	97.25	92.82	95.65
4	01.25	92.97	88.32	98.02	93.92	98.40	94.50	90.42	94.65	97.24	92.35	95.45
5	01.05	92.60	88.35	98.57	94.00	97.97	94.21	90.48	94.87	97.20	92.00	95.15
6	00.54	92.22	88.38	98.80	94.08	97.52	94.00	90.55	95.00	97.15	91.75	94.95
7	199.65	91.87	88.40	98.95	94.10	97.34	93.38	90.72	95.15	97.04	91.55	94.93
8	93.00	91.40	88.58	99.00	94.08	97.04	93.25	90.78	95.30	97.03	91.45	94.85
9	97.58	91.10	88.80	99.45	94.02	96.55	93.28	90.96	95.70	97.85	91.75	94.60
10	96.00	90.75	89.15	99.55	93.87	96.32	93.05	90.90	96.75	98.24	92.35	94.00
11	95.72	90.45	89.52	99.35	93.75	96.08	92.92	90.78	97.85	98.35	92.90	93.45
12	95.10	90.22	89.70	99.42	93.78	96.05	92.78	90.60	98.15	98.70	93.05	92.75
13	95.05	90.07	89.98	99.37	93.85	95.85	92.62	90.67	97.95	99.10	93.08	92.25
14	96.15	89.72	90.18	99.33	94.05	96.85	92.68	90.78	97.55	99.68	93.05	92.25
15	96.80	89.48	90.35	99.30	94.70	97.55	92.79	90.82	97.20	200.45	93.02	92.38
16	97.75	89.32	90.48	99.28	94.83	97.45	92.62	90.72	96.87	01.00	92.92	92.55
17	98.45	89.22	90.68	99.50	94.75	98.88	91.78	90.60	96.70	00.75	92.72	93.43
18	98.92	89.12	90.80	200.02	95.35	98.32	91.32	90.72	96.62	00.30	92.50	94.55
19	99.30	89.02	90.95	00.83	97.40	95.85	91.22	91.62	96.73	01.00	92.35	94.50
20	99.70	88.00	91.07	01.50	97.35	95.50	90.98	98.30	96.90	199.82	92.33	94.00
21	200.00	88.97	91.22	02.28	96.80	95.25	90.58	204.50	97.25	99.45	92.25	93.65
22	00.22	89.00	91.38	02.08	96.05	95.47	90.18	04.85	97.55	99.55	91.85	94.32
23	00.28	89.02	91.55	02.08	95.30	90.08	90.06	03.76	97.45	200.55	90.85	94.50
24	00.15	88.90	91.75	03.35	94.55	90.52	89.08	01.00	97.42	01.83	90.25	94.45
25	100.78	88.85	92.00	03.55	93.62	96.08	90.10	199.00	97.30	02.25	190.67	94.03
26	98.88	88.30	92.27	03.72	92.66	96.05	90.38	98.05	97.22	02.58	99.95	93.60
27	97.70	88.70	92.58	03.78	91.92	96.52	90.70	98.55	97.10	02.88	200.00	93.55
28	96.05	88.62	92.83	03.65	91.28	96.35	90.55	95.43	97.05	03.08	91.85	94.28
29	94.98	88.50	93.08	03.55	90.70	96.05	90.30	.....	97.00	03.30	93.52	95.00
30	94.47	88.42	93.62	03.47	90.15	95.95	90.12	.....	96.98	03.42	94.15	95.94
31	94.05	88.35	.....	03.42	.....	95.92	90.42	.....	97.00	.....	94.70	.....

M.—Record of gauge at Gray's Point, Missouri, for the fiscal year ending June 30, 1882.

[Height of water above a plane 200 feet below the Saint Louis City directrix.]

Day.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1	109.16	102.90	.....	100.01	110.41	109.01	104.91	105.01	114.10	108.60	111.60	114.70
2	09.00	02.31	.....	100.61	10.41	08.10	04.61	05.11	13.06	08.66	11.70	15.01
3	09.66	02.01	.....	02.11	10.41	07.51	04.06	05.11	12.51	08.66	11.66	15.31
4	10.46	02.20	.....	03.41	10.46	08.96	03.51	04.70	11.61	09.51	11.41	15.41
5	10.76	01.56	.....	05.51	10.01	06.51	02.96	04.70	10.66	06.16	10.91	15.31
6	10.66	01.20	.....	06.16	10.66	05.96	02.61	04.61	10.00	05.76	10.41	15.01
7	10.30	00.61	.....	06.31	10.01	05.60	02.26	04.41	09.60	05.41	10.01	14.66
8	09.60	00.40	.....	06.46	11.01	05.06	01.86	04.11	09.41	05.41	11.11	14.41
9	09.20	00.06	.....	07.30	11.01	04.66	01.61	03.96	09.10	05.16	10.66	14.16
10	08.91	00.56	.....	07.01	10.91	04.16	01.61	03.76	09.41	05.51	11.16	13.91
11	06.91	99.21	.....	07.26	10.66	03.76	01.86	03.51	09.41	06.41	11.31	13.66
12	06.01	99.01	.....	07.16	11.01	03.51	01.76	03.06	10.31	06.76	12.11	12.66
13	05.16	98.66	.....	07.56	10.91	03.16	02.06	02.76	10.76	07.01	12.51	12.01
14	04.70	98.36	96.96	07.66	11.01	03.61	02.66	02.61	10.91	07.41	12.66	11.16
15	05.41	98.10	97.26	07.61	11.31	03.61	03.06	02.51	10.61	08.41	12.61	10.76
16	05.30	97.60	97.51	07.41	12.11	04.51	03.66	02.66	10.11	09.41	12.61	10.66
17	06.66	97.46	97.66	07.21	12.66	05.41	04.26	03.61	09.51	10.36	12.31	10.66
18	07.31	97.26	97.96	07.26	13.16	05.26	04.41	03.76	09.01	10.31	12.01	11.11
19	07.66	97.26	98.61	07.46	14.06	04.66	04.16	03.96	08.61	09.91	11.76	12.66
20	07.91	97.36	98.76	08.16	15.91	04.26	04.06	05.51	08.51	09.41	11.61	13.26
21	08.16	97.16	98.76	08.91	16.46	03.66	04.16	12.66	08.66	09.01	12.01	13.41
22	08.36	97.26	98.76	09.66	16.31	03.41	04.26	17.91	08.66	08.66	11.91	13.66
23	08.36	97.06	99.01	16.46	15.66	03.16	04.41	19.16	08.51	08.51	11.61	14.01
24	08.41	97.16	99.16	10.66	15.21	03.61	04.41	19.51	08.31	09.11	10.91	14.41
25	08.51	97.06	99.31	11.01	14.66	04.41	04.51	19.01	08.11	09.16	10.16	14.61
26	08.06	97.06	99.36	11.16	13.46	05.26	04.61	18.11	07.66	11.01	09.51	14.51
27	07.66	96.86	99.66	11.41	12.51	05.76	04.61	16.41	07.61	11.16	09.76	14.66
28	05.56	96.66	.....	11.41	11.41	06.01	04.76	15.31	07.26	11.31	10.41	14.01
29	05.31	.....	100.06	11.10	10.51	05.86	04.91	.....	07.11	11.51	11.41	14.30
30	04.20	.....	100.20	10.91	09.76	05.61	05.01	.....	06.91	11.61	13.36	14.66
31	03.41	.....	.....	10.41	.....	05.26	05.01	.....	06.66	.....	14.01	.....

1640 REPORT OF THE CHIEF OF ENGINEERS, U. S. ARMY.

N.—Depth of water upon the bars between Saint

Date.	Stage above standard low-water by Saint Louis gauge.*	Name of steamer furnishing report.	Arsenal Island (head). Feet.	Arsenal Island (foot). Feet.	Hornet tail (middle). Feet.	Hornet tail (lower, Car-roll's Island). Feet.	Twin Hollows. Feet.	Widow Beard's. Feet.	Jim Smith's. Feet.	Bridge water of Foster Island. Feet.	Herculeum (swash in) Lucas. Feet.	Platin Rock. Feet.
1881.												
Aug. 3	11.20	City of Alton.....			9½	13½		10½	7(1)	10½		
4	10.80	Grand Tower.....	15		12			15	18½			
5	10.45	Ste. Genevieve.....			12			12		12		
6	10.45	Humphreys.....										
6	10.00	do.....			11	10		12	12	15		10½
7	10.00	Fearless.....				10½		10½	13½	0½	15	
7	9.75	City of Vicksburg.....	13½		10½			10½	8			15
8	9.20	Humphreys.....			10½	13						
11	8.10	W. P. Halliday.....	8½	13½	8			9	9			13½
11	8.10	Anita.....			10½	10½		9	9	9		15
12	7.85	Humphreys.....			9	9		8	8		7	13½
12	7.85	Ste. Genevieve.....			8	7½			11	8		
14	6.90	City of Greenville.....	10½		8½			8	9			12
16	6.60	Anita.....			8	10½		9	7	7		15
17	6.45	do.....										
17	6.45	Humphreys.....			8	6½		7	7½			10½
18	6.40	F. A. Blanks.....			6½	9		9	8		6½	
19	6.30	Humphreys.....			8	8		7	8½		7	9
19	6.30	Ste. Genevieve.....			6½			6½	6½	0½		
20	6.15	John Gilmore.....			6½	9		7	8½	6½		
20	6.15	City of Vicksburg.....	10½		7	7					7	9
21	6.00	Humphreys.....			7	7			9		8	9
21	6.00	Belle of Shreveport.....	9		7½	10½		8	9		9	
22	5.95	Anita.....										
23	5.90	City of Providence.....			7			8				
23	5.90	John Gilmore.....			7	10½		7½			6½	
24	5.90	Humphreys.....			7	7		9	9		7	9
24	5.90	Commonwealth.....			8½	9		6	6		8	
25	5.85	Humphreys.....										
25	5.85	City of Alton.....	8½		8			6½	9	6½		
25	5.85	Gold Dust.....			6½				8½		7	10½
26	5.60	Anita.....										
28	5.30	City of Greenville.....	9		6½	9	8	8	8		7	
29	5.15	Humphreys.....			7	7		7	8			
30	5.00	do.....									7½	
31	4.90	Anita.....										
Sept. 1	4.75	Humphreys.....	9		6½	6		6½	7		6½	7
1	4.75	Anita.....										
2	4.75	John B. Maude.....	12		6				6½	6		
3	4.60	Anita.....										
6	4.80	Humphreys.....	9½		6	7		8	7		5½	8
8	4.90	do.....	10½		7½	10½		8	8		8	8½
8	4.90	Belle of Shreveport.....	15	15	5½	9			9		10½	
8	4.90	Gold Dust.....			8							
8	4.90	Annie P. Silver.....	10½		7	7		7	10½		6½	
13	6.10	Humphreys.....	10½		8	10½		8½	10½		8	9
13	6.10	Commonwealth.....	9		7	9		7	9		7	
13	6.10	Montana.....	9		6½	9			8			
16	6.75	Humphreys.....	10½		8½	12		9	10½		9	10½
16	6.75	Anita.....										
16	6.75	John B. Maude.....			7			8		9		
16	6.75	C. P. Chouteau.....	10½		8½			9			6	
18	7.35	Will. Kyle.....							10½		9	
19	7.45	Jay Gould.....			8	9½						
20	7.50	Humphreys.....	12		9	12		10½	10½		10½	10½
24	8.15	do.....	12		9	12		10½	12		12	10½
30	9.50	Anita.....										
30	9.50	Humphreys.....	13½		12	12		12	12		0½	10½
1882.												
Feb. 2	6.15	City of Alton.....	15		7	9	7	9	7½		7½	9
3	6.10	Commonwealth.....			7	8	8	8	9		7	8
4	5.85	City of Vicksburg.....			6½							
4	5.85	Baton Rouge.....			7	9	8	10½	10½	8		9
7	5.95	City of Providence.....			7	7½	9	9	9			
9	6.25	A. P. Silver.....			7½	9½	8½	12	12	7½		12
12	6.25	City of Greenville.....			7½	9	8½	10½	12	7		
13	6.30	Ste. Genevieve.....			8½	10½		8½	12			
18	6.30	Halliday.....			7		9	9½	10½		8½	
17	6.35	Commonwealth.....			6½		8		10½		7	9

* Standard low-water, 4 feet above low water of 1863.

Louis and Cairo, as reported by pilots.

Cornish Island.	Selma (Kennett's Castle).	Forest Home.	Perry's T. H.	Rushtower Bend.	Fort Chartres.	Turkey Island.	Saint Genevieve Island.	Saint Genevieve Bend.	Kaskaskia Island. Fairy Island.	Saline Creek.	Saint Mary (Rozier's).	Mary's River (Block's).	Liberty Island.	Jones' Point.	Wilkinson's.
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
12			12		16½			12	11			12	9	9½	
12					16½			13	9½			12	9		
			12		18	16½	15	13½	12				10		
			8½					13½	12				8		
			10½		16½				8		13½	9½	8	9	
10½					16½	0		10½	0		10½	8½	10½	6½	
0			12		13½	12		9	9			9	6	8	
8			8		12	0	12	9	7			10½	6		
9½			8½		12		7	9	9			9	9½	6½	
			8		13½			9	8				12		
			13½												
8½			9		10½	9		9	8			0	6½		
9			9		10½			7	9			10½	9		
9			8		9	10½		7	10½			9	6½		
			6		9	8½		7	8			8	6		
								7	10½			8	6		
			7½	9	12	9		7½	16½			8½	6½		8½
8			8		13½	9		7	7		9	7			
10½			6½		12		12	6	9		9	8	6		
								7	7		9	9	10½		
									9			9	6		
9											7	8	6		
				8½				6			7	8½	5½		
13½	9½	9	8	9	9	9		6½	7		7	7	9		
	8	8	7½		12	12		7			10½	8	6½		
												6½	6		
			9	10½	12	6		7½			6	9½	5½		
			8		9½	7		5½	7		7	7	9		
					9			5½				8			
	6½	6½	8					6½				10½		5½	
	6							6½						5½	
	6½	7	8			7		6		6½		10½	9	6	
	8	6½	8½			7		5½	6½	6½		8	12	5	
												8		5½	
	7½		9			7½		6		7		8		6	
	8	8	8		10½	8		7		6		8	10½	7	
10½		7	9		10½	9		7		7		8		6	
	10½	9	9		10½	8		7½	9	8½		8½	10½		
	9							6½				12	8		
	8		8½					9						6½	
								9		8½			9	6½	
	9	10½	9		12	10½		9	9	9½		9½	12		
	10½		10½		12	10½		9	12	10½		9½	12		
												15	12		
	10½		10½		12	10½		10½	12	10½		10½	12		
	7		8		9	9		10½	8			8	7	10½	
	7		6½							8		8			
7½	7½		8	10½	12					8			6½	12	
7½	7½		9							8		9	8	9	
8	8		8		8½							10½	8	12	
7½	7½		9½							8		9	7	10½	
	7			8									9		
10½			9							8				10½	
	7		8							8		9	8		

1642 REPORT OF THE CHIEF OF ENGINEERS, U. S. ARMY.

N.—Depth of water upon the bars between Saint

Date.	Stage above standard low-water by Saint Louis gauge.	Name of steamer furnishing report.	Hat Island.	Crawford's.	Tea Table.	Moccasin Springs (Bee).	Kamburg.	Swift Shore.	Kinney Point.	Devil's Island (middle).	Floral Creek.
1881.	Feet.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Aug. 3	11.20	City of Alton.....	18	12					0	12	10½
4	10.80	Grand Tower.....	10½	12					15		9
5	10.45	Ste. Genevieve.....								8	
5	10.45	Humphreys.....									
6	10.00	do.....									
6	10.00	Fearless.....									7
7	9.75	City of Vicksburg.....		9				8½			9
8	9.20	Humphreys.....									
11	8.10	W. P. Halliday.....	9		9	13½		9	8½		8½
11	8.10	Anita.....	13½	8							7
12	7.85	Humphreys.....									
12	7.85	Ste. Genevieve.....		9							7½
14	6.00	City of Greenville.....		9							8
16	6.00	Anita.....									8
17	6.45	do.....	13½	8					9		8
17	6.45	Humphreys.....									
18	6.40	F. A. Blanks.....		6						8	8
19	6.30	Humphreys.....									
19	6.30	Ste. Genevieve.....								6	8
20	6.15	John Gilmore.....		7		12				7½	8
20	6.15	City of Vicksburg.....	10½	7½						7	8
21	6.00	Humphreys.....	10½	6½							
21	6.00	Belle of Shreveport.....	12	7		7½				8	7½
22	5.95	Anita.....	12	7					9		7
23	5.90	City of Providence.....									
23	5.90	John Gilmore.....		6½						8	8
24	5.90	Humphreys.....									
24	5.90	Commonwealth.....		7½						7½	8
25	5.85	Humphreys.....									
25	5.85	City of Alton.....		7		10½				8	8
25	5.85	Gold Dust.....	10½	8						5½	0
26	5.60	Anita.....	12	8					9	8	
28	5.30	City of Greenville.....		0						7	6½
29	5.15	Humphreys.....									
30	5.00	do.....									
31	4.90	Anita.....							9		8
Sept. 1	4.75	Humphreys.....									
1	4.75	Anita.....	18	6							
2	4.75	John B. Maude.....		7			9			6½	6
3	4.60	Anita.....	18	7					9		8
6	4.80	Humphreys.....									
8	4.90	do.....	8	6½						7½	7
8	4.90	Belle of Shreveport.....		6						8	8
8	4.90	Gold Dust.....									
8	4.90	Annie P. Silver.....		7						6	7
13	6.10	Humphreys.....									
13	6.10	Commonwealth.....		9						7½	8
13	6.10	Montana.....		8							
16	6.75	Humphreys.....									
16	6.75	Anita.....	18	9						9	9
16	6.75	John B. Maude.....		9						7½	
16	6.75	O. P. Chouteau.....								7½	
18	7.35	Will. Kyle.....		10½						9	
19	7.45	Jay Gould.....									
20	7.50	Humphreys.....									
24	8.15	do.....									
30	9.50	Anita.....	19½	12						15	13½
30	9.50	Humphreys.....									
1882.											
Feb. 2	6.15	City of Alton.....	12	8						9	
3	6.10	Commonwealth.....									
4	5.85	City of Vicksburg.....									
4	5.85	Baton Rouge.....		8			9			8½	
7	5.95	City of Providence.....		9			12			8½	8½
9	6.25	A. P. Silver.....		10½			9½			8½	
12	6.25	City of Greenville.....		8			9	10½		8½	
13	6.30	Ste. Genevieve.....		8½						6½	6½
13	6.30	Halliday.....		8½			0			8	
17	6.35	Commonwealth.....		8						9	

* Standard low-water, 4 feet above low water of 1863.

Louis and Cairo, as reported by pilots—Continued.

[illegible]

R 2.

IMPROVEMENT OF THE HARBOR AND MISSISSIPPI RIVER AT ALTON,
ILLINOIS.

The Mississippi River at Alton is shown on Plate XVI. The Alton landing lies just below a sharp turn in the Illinois bluff. The channel of the river for several miles above the city follows these bluffs in almost a straight line. Reaching Alton, it crosses to the head of Ellis Island, leaving comparatively dead water in front of the landing, the result of which is a shoal. This shoal at low water shuts off all access by vessels to the down-stream portion of the landing and renders access to the up-stream portion inconvenient.

The plan proposed by me, and adopted by a Board convened to consider the subject by my predecessor in 1880, was to construct a dike, AB, beginning at a point on the Missouri shore about $1\frac{1}{2}$ miles above the dam across Alton Slough and running diagonally down stream a distance of about 4,800 feet. If necessary, the dike was afterwards to be continued upon a line nearly parallel to the Illinois shore, which made a small angle with the first line of direction. The dike AB was designed to collect all the waste water of the river, and, throwing it against the channel as it came down the Illinois shore, to divert the channel and cause it to attack the shoal in front of Alton. It was to be built to a height of 14 feet above low water.

The execution of this plan was begun this year, but the method of construction adopted was different from that proposed in 1880. I believed at that time that it was worth while to try the permeable system in the Upper Mississippi, but I afterwards became convinced that the chances of its failure were much greater than those of success. Alton being situated above the mouth of the Missouri, it would not be judicious to apply it here. I accordingly prepared a design for a dike which should be substantial enough to resist of its own weight the destructive forces of the river. In its general outline it resembles the dams constructed upon the Illinois and Upper Mississippi for some years back, the principal new feature being the method of constructing the mattresses. Its details are shown on Plates XVII, XVIII, and XIX, and are fully described in the report of Mr. C. D. Lamb, assistant engineer, hereto appended, marked A.

The work was begun in September, but was suspended in October on account of high-water. This being the low water season, the foremen and plant were kept together, in the expectation that the rise was but temporary. This proved not to be the case, and in November the force was disbanded, only eight mattresses having been placed in position. The work was resumed about the 1st of April, and made satisfactory progress until the 17th of June, when the appropriation became exhausted and it was again suspended. The first or bottom tier of mattresses has been placed for a distance of 2,040 feet from the Missouri shore; the second tier for a distance of 780 feet; the third tier for a distance of 1,421 feet; and one mattress has been placed in the fourth tier.

The dike is about one-third completed. It has caused a strong current in the desired direction, which is now exerting a scouring influence upon the shoal in front of Alton. It will no doubt remove a part of the shoal, but to fully complete the work it should be extended and raised.

The work was under the direction of Mr. C. D. Lamb, assistant engineer, whose report is hereto appended and is intended to form part of this report. It contains the details of construction and of the different items of cost. He was aided by Mr. Gerald Bagnall, assistant engineer.

The expenditures were \$33,324.70, for which sum 23,700 cubic yards of dike were constructed. The cost was therefore \$1.41 per cubic yard, all contingencies being included. A more favorable working season would have largely diminished the cost.

Money statement.

July 1, 1881, amount available.....	\$33,324 70
July 1, 1882, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1881.....	33,324 70
Amount (estimated) required for completion of existing project.....	*51,075 30
Amount that can be profitably expended in fiscal year ending June 30, 1884.	16,700 00

A.

REPORT OF MR. C. D. LAMB, ASSISTANT ENGINEER.

ALTON, ILL., July 1, 1882.

MAJOR: I have the honor to submit the following report of operations for improving the harbor and Mississippi River at Alton, Ill., during the fiscal year ending June 30, 1882.

In accordance with your instructions received on September 16, 1881, I proceeded immediately to Alton and made arrangements for carrying on the work.

The river and harbor at that place seemed to have undergone but few changes since the survey of 1879, the most important being the increased size of the body of water passing down on the Missouri side of Ellis Island, this part of the river being much larger relatively than in 1879.

This change was due partly to the gradual lowering of the crest of the stone dike behind the head of Ellis Island, and partly to changes in the channel above, which caused a large body of water to run down next the Missouri shore. There had also been a gradual filling up of the lower part of the harbor on the Illinois side, but on account of the prevailing high stages of river, steamboats have experienced no difficulty during the past year in landing at any part of the wharf above the ferry dock, which lies at the foot of the improved levee.

Operations were begun as soon as the plant had been towed to the location of the work, and conducted in accordance with your letter of instructions dated September 16, 1881, of which the following is the substance:

"The dike A B is to be built to a height of 14 feet above low-water, made of brush mattresses loaded with stone, sunk tier upon tier, as shown in section on Plate XVII, each layer to be kept horizontal, filling the deepest parts of the line first. The lower tier sunk in juxtaposition with guide-piles, driven 40 feet apart, upon the line marking the down-stream edge of the dike, and each succeeding tier to be set back 8 feet from the down-stream edge of the tier below. The mattresses to be 42 feet wide, 2 feet 6 inches thick, and of a length convenient for handling, constructed upon a grillage composed of eight continuous poles, fixed 6 feet apart, running lengthwise of the mattress, and held in position by cross-poles at intervals of 25 feet. Upon this grillage a layer of brush 15 inches thick to be placed athwart the poles, then a second layer of the same thickness, to be placed at right angles to the first; upon this layer a grillage of poles to be placed athwart the mattress, as shown in the plan and elevation of Plate XVII. The whole to be sewed through and fastened at each intersection of the grillage poles with annealed wire."

The line of the dike was located and the driving of guide-piles began September 27. The extension of the line was continued, with frequent interruptions for the purpose of driving clumps of mooring piles and repairing breaches made by drift, until November 5, when the guide-line had been extended to a length of 3,600 feet. The driving of piles was then discontinued.

The construction of mattresses was begun as soon as a supply of brush could be procured, and continued until six mattresses had been placed in the deep water near the shore end of the dike, five on the bottom and one on the second tier. One mattress was lost, after being partly sunk, by the breaking of the lines used to hold it in position.

* Estimate of last year diminished by \$35,000, the amount allotted by Congress from appropriation of August 2, 1882, for improving Mississippi River from Cairo to the Illinois River.

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Work was suspended October 23 on account of the high stage of water which covered the bottom land near the dike, where the mattresses were being constructed. The force was not, however, disbanded, and two mattresses were left upon the ways partly finished, as it seemed probable that the river would soon subside. But as the water continued to rise during November, and reports from the upper river gave no hopes of an immediate fall, the two mattresses on the ways were completed and placed, one on the second, the other on the shore end of the third tier. Work was suspended for the season November 22, when the tow-boat was turned over to its owners, the equipment having been put into winter quarters behind Ellis Island.

In accordance with your letter of instructions dated November 12, 1881, the plant and material on hand were turned over to Assistant Engineer D. M. Currie, the barges being towed to Saint Louis by the steamer A. A. Humphreys and laid up behind the foot of Carroll's Island.

In accordance with your letter of instructions dated March 23, 1882, operations were resumed April 3.

But little change had taken place in the harbor since the work was suspended in the fall. The bar at the outer end of the dike had moved down stream about 300 feet, while the erosion of the Missouri shore above and below the dike had become very marked, but the shore end of the dike rested upon a hard clay bank, filled with roots, which showed no signs of cutting.

The mattresses placed during the fall season were found in position, but most of the guide piles had been carried away by ice and drift during the winter.

The driving of guide piles was begun April 10, and continued until the line had been repaired to a length of 3,000 feet. The pile-driver was then towed to Saint Louis May 4.

The construction of mattresses was begun as soon as a force of laborers could be organized and the ways repaired, the material on hand at the close of the fall season having been returned by Assistant Engineer D. M. Currie.

Forty-seven mattresses, each 80 feet long, were constructed and placed during the last half year; of which number twenty-one were placed on the bottom tier, extending it to a length of 2,040 feet; eight on the second tier, completing it to a distance of 780 feet from its shore end; seventeen on the third tier, which was extended to a length of 1,420 feet; and one on the shore end of the fourth tier, which also served to protect the bank at the head of the dike, being assisted by a revetment of stone, which extended about 100 feet above the dike.

The appropriation being nearly exhausted, work was suspended June 17. The force was disbanded and paid, the equipment towed to Saint Louis, and the tow-boat turned over to its owners.

The total number of cubic yards of dike constructed during the year was 23,700, of which the total cost was \$33,324.70, or \$1.41 per yard. The cost of the work done during the first half year was \$2.90 per cubic yard, the season being a most unusual one on account of the heavy and frequent rains and the resulting high stage of river. The cost of the work done during the last half year was but \$1.10 per yard.

The total number of linear feet of mattress constructed during the year was 4,400. Of this number 4,329 linear feet were successfully placed.

The total cost of building and placing a mattress 100 feet long, 42 feet wide, and 2½ feet thick was as follows:

112 cords of brush, at \$1.94	\$217 28
136 pounds of wire, at 4.96 cents	6 76
44 pounds ½ Sisal rope, at 7.7 cents	3 11
14.3 pounds Sisal hide rope, at 7.6 cents	1 09
Cost of material	228 24
Labor of actual construction	116 39
Equipment	11 81
Miscellaneous, labor, and contingencies	110 21
Cost of mattress ready for placing	466 65
Labor of placing	\$49 37
152.7 cubic yards of stone, at \$1.05	161 07
Towage	77 39
	287 83
Total cost of mattress in position	754 48

Of the foregoing cost, 30 per cent. was expended for the material and 16 per cent. for the labor required for the actual construction of a mattress 100 feet long; the stone and labor of placing, from 21 and 6 per cent., respectively, of the whole amount; while 27 per cent. was the aggregate amount expended for tools, equipment, engineering, and contingencies.

The number and position of the mattresses placed during the year is shown in plan and elevation on Plate XVIII.

Referring to this plate, it will be seen that the crest of the dike has been raised to a nearly uniform height of about 7 feet above low water, a little higher than the top of the bar at the lower end of the line.

The placing of mattresses on the bottom tier was discontinued for a time after it had been extended to a length of about 1,000 feet, but as the current sets strongly across the line of the dike at this point, the bottom began scouring around the outer end of the tier, and work upon it was resumed and continued until its outer end was nearly in its present position. No scour around the end of the mattresses has since been perceptible, as the current at the end of the line sets over toward the water-works, running nearly parallel to the dike.

The effect of the dike in its present form upon the harbor below cannot be estimated until a low stage of river, but a large body of water is turned over toward the Illinois shore, and it seems probable that a good and convenient landing may be found during the lowest navigable stages at any part of the levee above the ferry landing.

A survey of the harbor was made during the latter part of June, with the river about 23 feet above low water. The soundings* taken at that time are shown in black on Plate XVI. They indicate that the bar at the foot of the harbor has moved down stream several hundred feet since 1879, and the low water channel is much nearer the levee.

In constructing mattresses, the brush was placed so as to break joints as much as possible. The small ends of the brush were allowed to project for several feet beyond the ends of the mattresses, to close any gaps left between them when placed, and the bottom layer of brush was so arranged as not to catch upon the ways while the mattress was being launched. The bottom grillage-poles were fastened to the way-pieces with lashings of hide rope until the mattress was ready for launching.

The mattresses were wired or stitched with needles made in accordance with your verbal instructions. These needles were 4 feet 6 inches long, of three-fourths-inch round iron, with a slot near the point, and fitted with a wooden shank, as shown in Plate XIX, Fig. 1. In using these needles the wire is cut into pieces about 32 feet long. A piece is doubled and pulled under a top pole of the mattress at its intersection with a bottom grillage. This position is shown in Fig. 2. The ends are then crossed and thrust down through the mattress, two needles being used as shown in Fig. 3. One end of the wire comes through the mattress on each side of the bottom grillage-pole. Both ends are then taken out of the needles by the workmen underneath, pulled taut, and again crossed, as in Fig. 4. The ends are then pulled up through the mattress as the needles are withdrawn, and fastened with pliers. Figs. 5 and 6 show the position of the ends before and after fastening, respectively.

The length of the mattresses constructed during the year was limited to 80 feet. That size was as large as it seemed expedient to handle in the strong current flowing across the dike. Larger mattresses might successfully have been placed, but in case of accident would have been lost, as it was found by experience that a mattress 80 feet long which had been carried below the dike could be towed back over the line only by a large expenditure of time and taxing the power of the tow-boat to its utmost.

The mattresses were at first constructed upon the floating ways designed for use in improving the Mississippi River at Horsetail Bar, and described in the Report of the Chief of Engineers, United States Army, for 1880, page 1380. Considerable delay was caused by the breaking down of these ways, the weight of the mattresses being greater than they were able to sustain. They were finally disabled and abandoned October 15. Meanwhile the construction of fixed ways on shore near the upper end of the dike had been completed. These ways were made of 3 by 6 inch oak pieces, 42 feet long, set 5 feet apart on rows of 10-inch posts. The ways were continuous and could be used for constructing a single mattress 210 feet long. They were used as described during the fall season, but were undermined and made useless during the winter, and they were entirely reconstructed upon resuming work in the spring. Their inclination was then increased to about 5 on 1 to facilitate launching, and the space between the way-pieces was increased to 7 feet. As the river fell in April a shoal appeared in front of the ways, and their lower ends were extended out 24 feet by oak pieces, resting on posts driven by the pile-driver. The river soon rose again and rendered necessary the extension of the upper ends of the way-pieces, which were lengthened about 12 feet.

After launching, the mattresses were dropped down by the tow-boat alongside a barge loaded with stone, and anchored just above the dike. The barge and mattress were held in position by head and lines leading from the barge to mooring-piles or anchors placed about 1,000 feet above the dike. Mooring-piles were used during the fall season, but they were found liable to be overturned, and they interfered with the handling of the tow-boat. Their use was finally abandoned in favor of anchors, two of which, with an aggregate weight of 900 pounds, were attached to each line, 150 feet

* Soundings omitted on small scale map.

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apart. The barge and mattresses were swung into the exact position required by lines made fast to guide-piles. About six mattresses could be placed without moving the anchors.

The mattresses were attached to the barge while being sunk by slip-lines, passing through loops in the corners of the mattress. These loops were of three-quarters-inch Sisal rope, and as it is passed three or more times around the top and bottom grillage-poles, including a considerable quantity of both tiers of brush, as shown at L in the plan and elevation of Plate XVII, it affords a very strong fastening.

It was found that the mattresses as originally constructed were too rigid to bend into the desired position when placed on the second tier. To insure greater flexibility the bottom layer of brush running athwart the mattress was made less than 15 inches thick, and the small ends of the top grillage-poles were placed so as to point up stream. The second tier of mattresses was sunk with its down-stream edge about 12 feet above the guide-piles, but with these precautions it was generally several days before mattresses placed on this tier bent down into position.

The total quantity of material used on the work during the year, with its cost, exclusive of labor and towage, was as follows:

Brush	cords ..	4,909.1	\$278 86
Stone.....	cubic yards..	6,594.9	4,946 18
Piling, 17 $\frac{1}{2}$ sticks.....	linear feet..	7,432	261 69
Wire.....	pounds..	6,000	297 50
Rope, $\frac{1}{2}$ -inch Sisal	do	1,936	148 79
Rope sisal hide	do	630	47 93
			<hr/>
			5,920 95

The brush used was procured by hired labor from tow-heads near the harbor and in the Missouri River. The cutting of brush was delayed and rendered more expensive than usual by frequent removals of the force and equipment engaged in that work. These removals were made necessary by the slight elevation of the tow-heads above the surface of the river at an accessible stage.

The stone was furnished by the Grafton Quarry Company, delivered upon government barges at Grafton.

A part of the piling used during the fall season was delivered upon barges near the work by contractors, and the balance was cut by hired labor from Piassa Island, and rafted to the work. A supply of cottonwood piling was obtained from Piassa in the spring, but they were not strong enough to withstand the strong current and heavy drift running across the dike, and a supply of heavy oak piles was obtained from the work at Twin Hollows, east bank.

I have been ably assisted in prosecuting the work by Mr. Gerald Bagnall, assistant engineer, who was assigned to the work on the 1st of May.

Very respectfully, your obedient servant,

C. D. LAMB,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

R 3.

ICE HARBOR AT SAINT LOUIS, MISSOURI.

There was nothing to add to the history of this work up to the close of the fiscal year. It had not been begun, the appropriations, amounting to \$60,000, being held until further action by Congress. The river and harbor act of August 2, 1882, contains the following proviso:

That the unexpended sums heretofore appropriated for an ice harbor at Saint Louis, Mo., be, and the same are hereby, transferred and appropriated, to be expended under the direction of the Secretary of War, for the improvement of the channel of the Mississippi River opposite the city of Saint Louis, Mo., by repairing and raising the present low dam across the channel east of Arsenal Island, known as Cahokia Chute, and by the construction of such other works in or near said Cahokia Chute as may be deemed advisable to accomplish the same purpose.

The work under its present title therefore disappears from the list of those under my charge. The funds will hereafter be accounted for un-

der the title of "Improvement of the channel of the Mississippi River opposite the city of Saint Louis, Mo."

Money statement.

July 1, 1881, amount available.....	\$60,000 00
July 1, 1882, amount available.....	60,000 00

R 4.

IMPROVEMENT OF THE MISSISSIPPI RIVER AT OR NEAR CAPE GIRARDEAU, MISSOURI, AND MINTON POINT, ILLINOIS.

The state of affairs existing at this locality before the works were begun is shown on Plate XX, constructed from the survey of 1880. Beginning at Kinney Point, on the Missouri side, the channel crossed over to Devil's Island, followed that shore down to near the foot of the island, and then crossed back to the Missouri shore, spilling over a considerable quantity of water in the direction of Minton Point.

Following the Missouri shore down as far as Cape Rock, the channel then gradually found its way again towards the Illinois shore, its direction here being the resultant of two principal components, viz, the main body of water flowing by Cape Rock, and that flowing by Minton Point. Thus far the location of the channel was favorable for furnishing deep water to the Cape Girardeau landing. Following its general law, its tendency was to leave the Illinois shore somewhere above Wahoo, and, crossing again, to strike the Missouri shore just above Cape Girardeau, and to flow along the front of the town. In its effort to do this it was impeded by the long conical bar which, beginning just below Cape Rock, extended out like an index-finger towards the middle of the river and down in front of Cape Girardeau, leaving deep water inside of it next to the town. Forced out of its natural course the channel was split up into several lines of deepest water, one of them returning to the Illinois shore, and two of them, after being reunited, passing over to the lower extremity of the Cape Girardeau landing. On neither of these lines could more than 4½ feet be carried through at low water, and the width for that depth was so small and the difficulty of following it was so great that practically a considerably less depth was available for navigation. A navigable depth of from 5 feet to 5 feet 4 inches was constantly reported by pilots during the autumn of 1880, at stages from 4 feet to 4 feet 4 inches above low water. This state of affairs was injurious not only to the town of Cape Girardeau, but also to the general navigation interest. In order to reach the town, boats were compelled to approach from below; and in leaving it, to back out. The bar was growing, and threatened to cut off access altogether.

To correct these evils it was necessary to collect all the channels opposite Cape Girardeau into one, and force that one through the long conical bar before described. The thickness of the bar, measured on the line of the proposed channel, was about half a mile. To close the existing channels by a single dike, built opposite the town, would have been to place in the river an obstruction to navigation which for the time being would be a greater nuisance than the bar. Moreover, such a dike would necessarily be expensive and difficult of execution, since it must form a greater obstruction to the flow than a bar half a mile thick. A different solution of the problem was sought, in the belief that it was

not necessary to limit the location of the works to the immediate vicinity of the obstacle. In my project of January 12 1881,, I said:

The comparatively feeble scouring power of the river is due to the dispersion of its waters. In the present condition of the Mississippi a dispersion occurs at nearly every crossing. A dispersion at one crossing reduces the volume and the living force of the channel, and sends down to the next crossing a considerable body of water to contend with instead of aiding it, thus rendering a further dispersion much easier. The dispersion here facilitates the next, and so on. If works be constructed to concentrate the water at any one crossing they cannot fail to have a beneficial effect upon all the crossings for a long distance below. A limit will finally be reached, however, when the benefit will cease to be visible and practical. What that limit is can be ascertained only by experience. It is believed that 3 or 4 miles, which will generally include two or three crossings, is far within the limit, and that it may be assumed with certainty that the works designed for the improvement of one crossing may be distributed over all the crossings for a distance of at least 3 or 4 miles above.

A dike, E F, was accordingly proposed near Minton Point, to run out from the foot of Devil's Island obliquely down stream. The function of this dike was to shut off the flow towards Minton Point, and to send the river down from this place in concentrated shape. The channel issuing from Cape Rock would have no contending stream to force it out of its natural path. It would cross over to the Illinois shore in a compact body, and returning against the Cape Girardeau bar, would strike it as one immense jet of water. It was not expected that this dike alone would complete the removal of the bar. A dike, C D, opposite Cape Girardeau, was designed to complete the work. It was to be constructed after the completion of the work near Minton Point, when it was expected it could be placed without interfering with navigation.

Before the works could be begun a number of changes from the conditions shown on the map occurred, the most important of which were a large increase in the volume of water flowing by Minton Point and a marked increase in the height and size of the bar in the front of Cape Girardeau. The volume flowing by Minton Point was about equal to that in the steamboat channel, and had an equal depth. Heavy caving of the bank was going on near Minton Point. The bar in front of Cape Girardeau had received deposits from 10 to 15 feet in thickness, and portions of it were dry at a stage $18\frac{1}{2}$ feet above low water. At its lowest point, towards its upstream end, there was a depth of but $2\frac{1}{2}$ feet of water at a stage 7.2 feet above low water. The width of the deep water inside the bar next to the landing was diminished to from 200 to 400 feet. These changes did not involve any important modifications of the plan, but they indicated the necessity of its immediate execution.

The work was begun in August last, near Minton Point, the system of construction employed being the same as that used under my direction elsewhere upon the river below the mouth of the Missouri. Within a month after beginning the work its influence upon the Cape Girardeau bar was perceptible.

The primary hurdle E F was still unfinished when the water began to cut through the bar and to wash away the side of it next the town. This action increased as the works progressed, until there was in October a navigable channel over the bar and a strong draught of water down the shore inside. A heavy rise in the river at this time hastened the work of excavation. By the 1st of December the bar had practically disappeared. The desired object had thus been attained by the construction of works located more than 3 miles distant, and without in any manner obstructing navigation. The works opposite Cape Girardeau became unnecessary except as a preservative. In that capacity, however, they were considered important. The prolonged high-water of last autumn and this spring has caused material changes in

the location of the channel in the vicinity of Devil's Island and above. Under the new circumstances, the works erected last autumn could not be expected to keep the channel permanently in front of Cape Girardeau, notwithstanding the fact that they caused it to go there. To insure its present location under all circumstances of approach from above, the works opposite the town are required. They were begun in April, but the original plan was modified by leaving out all the secondary hurdles, retaining only the primary hurdle O D. At the end of the year this hurdle had reached a length of 600 feet.

Enlarged sections of the river in front of Cape Girardeau, taken on the line A B, are given on Plate XX. They show the dimensions of the bar at that point at the time the works were planned, at the time they were begun, at the end of the working season last autumn, and at the end of the fiscal year.

These works were under the local supervision of Mr. J. A. Worthen, assistant engineer, from whose report extracts are hereto appended, marked A, to which attention is invited for details.

The expenditures were \$43,520.96, of which amount \$25,179.84 was specially appropriated by the river and harbor acts of June 14, 1880, and March 3, 1881, and the balance was allotted from the general appropriation for the improvement of the Mississippi River between the Illinois and Ohio rivers.

To complete the original project there remained to finish the hurdle opposite the town and to protect the bank.

Money statement.

July 1, 1881, amount available.....	\$25,179 84
July 1, 1882, amount expended during fiscal year, exclusive of outstanding liabilities July 1, 1881.....	25,179 84
Amount (estimated) required for completion of existing project.....	*41,820 04
Amount that can be profitably expended in fiscal year ending June 30, 1884.....	42,000 00

REPORT OF MR. J. A. WORTHEN, ASSISTANT ENGINEER.

CAPE GIRARDEAU, MO., July 17, 1882.

MAJOR: I have the honor respectfully to submit my annual report of operations for improving the Mississippi River, near Cape Girardeau, Mo., and Minton Point, Illinois, conducted under your direction, during the fiscal year ending June 30, 1882.

Plate XX is a sketch of the river near Cape Girardeau and Minton Point, showing its general features, channels, and sand-bars as they appeared in September, 1880, river at a 9-foot stage.

The changes which took place from low water, 1880, to low water, 1881, were such as to excite grave apprehensions for the future of the harbor at this point.

In August, 1881, the dry bar terminating the projected hurdles near the foot of Devil's Island had entirely disappeared, there being 12 feet of water at the point F, and a small bar had made out from the foot of the island.

The bar above Cape Rock had increased to double its former size, and the long conical bar, which, beginning just below Cape Rock, extended out towards the middle of the river and down in front of Cape Girardeau Landing, had assumed enormous proportions. The dry portion, as shown upon Plate XX, had changed its form, without materially affecting its area, while the lower portion, in front of Cape Girardeau, had received deposits 10 to 15 feet in depth. This latter portion of the bar, about 4,000 feet in length and from 200 feet to 600 feet in width, beginning opposite the mouth of Sloan Creek and extending down past the levee about 500 feet, was then dry, its crest rising to a height corresponding to an 18.5-foot stage of the river.

* Estimate of last year diminished by amount allotted from funds appropriated for improving Mississippi River between Illinois and Ohio rivers.

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Between the bar and the landing was a narrow channel from 200 feet to 400 feet in width, with a depth of 18 feet below the levee, 9 feet at the mouth of Sloan Creek, and $4\frac{1}{2}$ feet over the head of the bar. The lowest stage of water during the year occurred in September, and was 7.2 feet; the depth of water over the head of the bar was then but $2\frac{1}{2}$ feet. The only access to Cape Girardeau levee at this time was around the foot of the bar and up this narrow channel.

Descending steamers were compelled to pass the city and run up behind the bar, backing out as they had come in.

The steamboat channel, beginning at the head of Devil's Island, followed along the western bank to near its foot, then crossing to the Missouri shore at Little Floral Creek, followed that shore past Cape Rock into midstream and held nearly a due course to the government light, then on the point of rocks near the southern boundary of the city of Cape Girardeau, touching the Missouri shore again at this point.

The shallowest water in this channel at any time during the season was 6.5 feet, and was found on the crossing from Devil's Island to the Missouri shore at Little Floral Creek.

Leaving the steamboat channel near the foot of Devil's Island was another channel, making a slight detour around the foot of Devil's Island to Minton Point, then gradually finding its way back to the middle of the river, joining the steamboat channel again just below Cape Rock. Although this channel was more direct than the former, and contained the same depth of water, its course not having been definitely marked, was not known to pilots.

Among other changes, the most noticeable was the inroads of the river upon the Illinois shore the entire distance from the mouth of the chute south of Devil's Island to and below the site of the proposed works opposite Cape Girardeau. This cutting of the bank varied at different points from 30 to 50 yards, being greatest at Minton Point, where the erosion was still going on, and continued until the works at this point had advanced for a time and its effects had begun to be felt.

I. LOCATION AND EXTENT OF WORKS CONSTRUCTED DURING THE YEAR.

The fiscal year just closed has been remarkable for its protracted period of high water throughout the Mississippi Valley, and especially in the lower river country.

For three-fourths of the year the river at Cape Girardeau was above a 15-foot stage, and during the months of October and November, 1881, and April, May, and June, 1882, it ranged from 20 feet to 28 feet, a greater portion of the time oscillating between 23 feet and 28 feet. This unprecedented occurrence, frustrating every attempt to predict the rise and fall, or the probable action of the river, has obstructed the progress of the work and greatly increased the cost of construction.

The long and mild winter of unusually high water divided the year into two distinct working seasons.

Following the operations of the fiscal year in their chronological order, the work done during each half year has been described separately.

The plant having been prepared, its transfer from Saint Louis to Minton Point, Illinois, the site of the work first to be constructed, was begun August 10, and with other preliminary arrangements occupied a period of seven days.

On the 18th day of August the primary hurdle line E F at Minton Point was located. At this time, the river at a 9-foot stage, about 650 feet at the shore end of the hurdle line was across a dry bar, * * * the crest of the bar corresponding in height to a 10 $\frac{1}{2}$ -foot stage of water.

To complete the hurdle as it advanced and close the gap which otherwise would have existed, it was necessary to make the shore connection by an offset hurdle, * * * leaving the shore 250 feet upstream from the point E, where was found sufficient depth of water to float the pile-drivers, and joining the hurdle line beyond the bar. * * *

On the 19th four pile-drivers commenced driving piles at different points along the bar.

The piles in the hurdle line were in the main driven 6 feet apart, the hurdle to be constructed by hurdling or wattling the brush directly upon the piles.

The brace-piles for receiving the foot of the braces were driven at intervals of about 20 feet, and at distances from the hurdle line which would give the braces an inclination of 45° , as near as might be.

As soon as the pile-driving had advanced to a suitable distance from the shore the footing mattress was begun and carried forward as fast as the piles were driven.

The hurdling was also begun and the several branches of the work moved on together, completing the hurdle as they advanced. The height fixed upon for the construction of this work was that of a 20-foot stage of the river.

On August 31 pile-driving in the primary line had reached a point 800 feet from the

angle at G, or about 1,500 feet from the point E at the shore end, when two pile-drivers were removed to secondary hurdles Nos. 2 and 3, and began driving piles in the shallow water at the bar.

The secondary hurdles were located in parallel lines at intervals of 400 feet, and differing from the primary hurdle in having no footing of brush to protect the bed against scour. Their construction has in all cases followed that of the primary hurdle. Work continued in this manner to the 1st of October, when the line of piling in the primary hurdle had advanced into 22 feet of water. It had now reached a point 350 feet beyond the channel, passing around the foot of the island to Minton Point, and was nearing completion, its extremity being about 200 feet from the point F. * * *

At this time the river was at a 12 foot stage, rising rapidly and carrying heavy masses of drift. As it continued to swell, the volume of water seeking the more direct channel to Minton Point was so large and its course apparently so fixed as to lead to the conclusion that this channel or some modification of it, in contradistinction to that crossing to the Missouri shore at Little Floral Creek, would be the main channel for all stages above a medium, if it did not result in the low-water channel.

The sudden rise of 3 feet in forty-eight hours from October 2 to October 4 sent down upon the hurdle * * * a body of water 25 feet in depth, loaded with drift, and flowing at a velocity not less than 4½ miles per hour. In its effort to follow the channel the current broke through the line of piling about 350 feet from its outer end. The waters rushing through the gap with irresistible force, rapidly eroded the bed, overturned the hurdle, and carried away one section of footing mattress 400 feet in length, which had been constructed, but could not be sunk into position on account of the accumulation of drift.

This erosive action continued along the hurdle line from the point where the mattress had been placed outward, and ceased only when that portion of the line of piling, 500 feet in length, which had been driven beyond this point, was destroyed.

At this time the primary hurdle was 1,756 feet in length, 1,475 feet of which was complete. In consequence of the detour at its shore end, the extremity of the hurdle was a point 1,025 feet from the shore or point E in direct line of location.

Estimating the amount destroyed during the season, the total length of primary hurdle driven aggregated 2,256 feet, and of footing mattress constructed, 2,156 feet.

To continue operations upon the primary hurdle under the difficulties then existing would have been extremely expensive and progress very unsatisfactory, if, indeed, any progress could have been made at all.

For these reasons work upon this hurdle was temporarily suspended, and was not resumed on account of high water, which submerged the hurdle and remained above a 20 foot stage till the close of the season.

While the work of extending the primary hurdle was thus delayed the construction of secondary hurdles Nos. 2, 3, 4, 5, and 6 progressed steadily from the time it was begun to November 19, when operations were suspended for the season.

Pile-driving advanced quite rapidly over the entire area protected by the primary hurdle, and would have completed the system of hurdles had it not been for the high water, varying from a 2.3 to a 28 foot stage, during the latter part of October and the month of November, which maintained a channel along the outer ends of the hurdles * * * from 25 feet to 30 feet in depth, with a current from 4 to 5 miles per hour.

The progress of hurdling was variable, and a greater portion of the time quite slow, as the depth of water was too great to admit of wadding the brush upon the piles, except for a short distance at the shore ends of the hurdles; and the ways upon which to construct curtains were in course of preparation.

The aggregate length of secondary hurdles driven was 5,329 feet, of which 2,101 were completed, except the bracing.

This work was distributed as follows: Hurdle No. 2, 791 feet driven, and complete; hurdle No. 3, 1,014 feet driven, 877 feet complete; hurdle No. 4, 1,292 feet driven, 364 feet complete; hurdle No. 5, 1,392 feet driven, 260 feet complete; hurdle No. 6, 840 feet driven and 600 feet complete.

Work was resumed April 20, with the river at a 22-foot stage.

High-water having prevailed a greater portion of the winter, the channels in the vicinity of Cape Girardeau had become fixed, and did not change perceptibly during the second half of the year. * * *

The damage done to the hurdles at Minton Point by the protracted floods was comparatively slight. The small breach near the shore end of the primary hurdle, which showed itself about the 1st of December, had enlarged to 130 feet; 50 feet of the outer end of hurdle No. 5, which extended into the channel, had gradually worn away; and 384 feet of the chute end of hurdle No. 6, falling within the violent eddy which had formed at the foot of Devil's Island, had been destroyed.

Immediately upon resuming operations the breach near the shore end of the primary hurdle was repaired. While this was being done the river advanced to a 23½-foot stage, again submerged the hurdles and rendered their extension impracticable. April 28

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operations at Minton Point were a second time suspended on account of high-water.

On the 27th day of April two pile-drivers commenced driving piles in the primary hurdle line opposite Cape Girardeau, and on the 28th a third joined them. Work upon this hurdle extended over a period of thirty-four days. At no time during this period was the water below a 22-foot stage, and on May 30 it had reached a 26-foot stage, when operations were temporarily suspended. The depth of water in which this hurdle was constructed varied from 21 to 30 feet. The force of the current was almost irresistible.

In addition, to these obstructions, severe storms, followed by high winds from the west-northwest, which prevailed for several days at a time, were frequent.

Under these difficulties the rate of progress upon this hurdle was necessarily slow, and the construction rendered much more expensive than it otherwise would have been.

The depth of water being too great to admit of brush being wattled upon the piles, the hurdle has been completed by constructing light curtains upon the ways prepared for the purpose, and launching them into position in a manner explained under "forms of construction."

In extending the hurdle it has been necessary to construct the footing mattress as fast as the piles were driven, and at the same time to brace the piles firmly, thus being better able to guard against losses by keeping as little space as possible between the pile-drivers and the braced hurdle.

As the hurdle advanced the resisting forces increased, and great difficulty was experienced in maintaining its line.

Pile-drivers, placed in position, with four 125-pound anchors for security, were drifted downstream and entirely out of reach of the hurdle. Clumps of piles, consisting of three piles in each clump, driven at intervals of about 200 feet, in a line as nearly as might be parallel to and about 150 feet upstream from the hurdle line, were resorted to for anchorage. These in many cases proved inadequate to withstand the strain brought to bear upon them by the pile-drivers while hoisting piles into the leads and lowering them to the bottom in 30 feet of water.

In some instances all the piles in the clump were broken off above the ground, and in others the tops of the clumps were drifted downstream in such a manner that the piles were pulled up.

Much difficulty has also been experienced in sinking the footing mattress, which was constructed in sections about 130 feet in length and 50 feet in width. Great care is required to maintain the mattress in position while descending to the bottom. It is sometimes the case that the mattress is improperly ballasted by loading the upstream edge too heavily at first, thus causing it to sink more rapidly than the downstream edge; just the reverse of what it should do. This has taken place in two instances, and the current, coming in contact with the upper surface of the mattress, forced it down against the piles after the manner of a curtain. The strains produced by this abrupt stopping of the current were enormous, and in both instances swept away the mattresses and destroyed nearly twice its length of the hurdle driven.

At the close of the year the primary hurdle opposite Cape Girardeau was 600 feet in length.

The hurdles driven and constructed during the year, including repairs, losses, &c., aggregate 8,880 linear feet, of which 2,386 linear feet was in the primary hurdle at Minton Point, 5,329 linear feet in secondaries at Minton Point, and 1,165 linear feet in primary hurdle opposite Cape Girardeau.

The height fixed upon as a standard to which the works were to be carried was that corresponding to a 20-foot stage of the river; but, on account of high water, this standard was deviated from.

At Minton Point the primary hurdle and secondaries Nos. 2 and 3 were carried to a 20-foot stage; secondaries Nos. 4, 5, and 6 were driven at a higher stage of water, and were left as follows: No. 4, at a 23-foot stage; No. 5, at a 24-foot stage; and No. 6, at 26-foot stage. Opposite Cape Girardeau the primary hurdle was complete to a 26-foot stage of the river.

2. FORMS OF CONSTRUCTION.

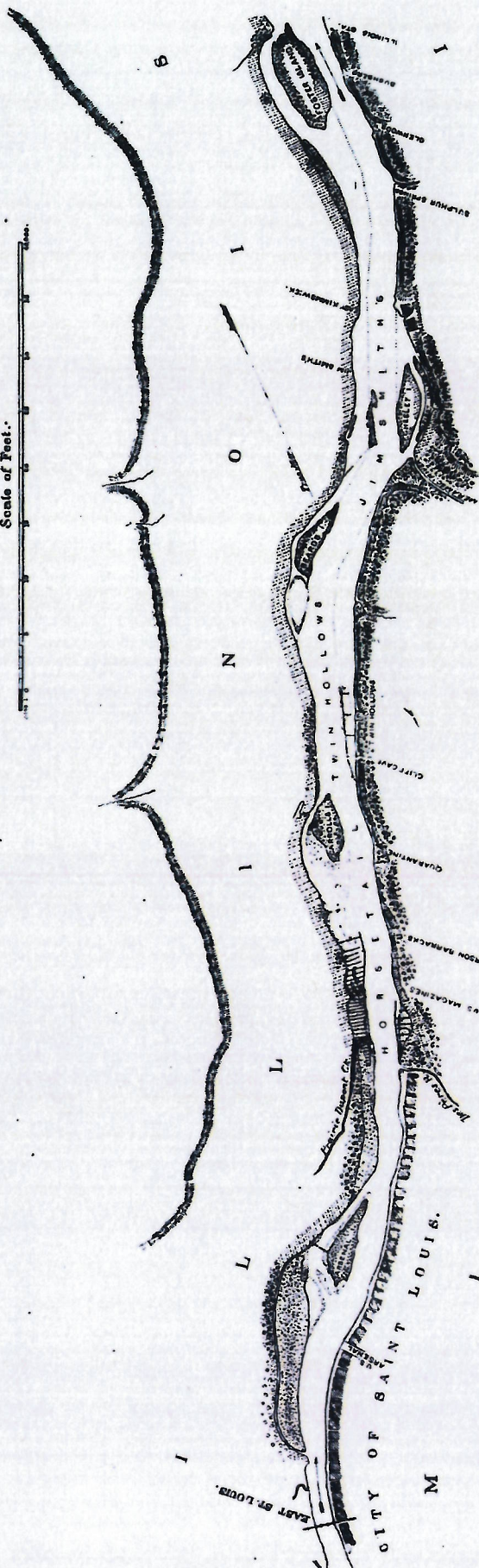
Regarding the detailed forms of construction very little need be said, as the report of Mr. D. M. Currie, assistant engineer, for 1881 upon this subject was very exhaustive.

The two general forms, the fixed hurdles and the curtain hurdles, have been used throughout the year. During the first half of the year the "fixed hurdle" was used entirely, the brush being wattled upon the piles in depths of water less than 18 feet.

The form of "curtain hurdle" used opposite Cape Girardeau, with detailed method

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C

MAP OF
MISSISSIPPI RIVER
FROM
SAINT LOUIS BRIDGE TO FOSTER ISLAND
Showing location of works of improvement.



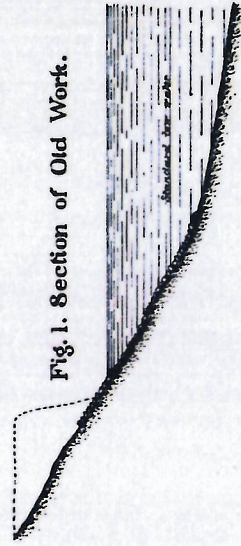


Fig. 1. Section of Old Work.

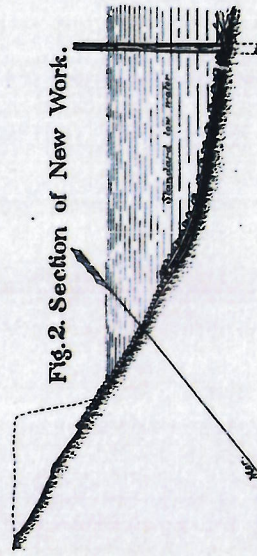


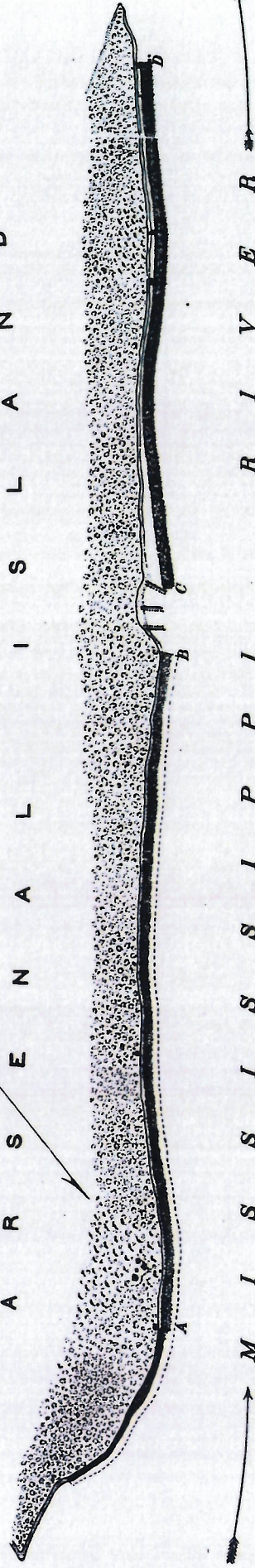
Fig. 2. Section of New Work.

ARSENAL ISLAND PROTECTION.

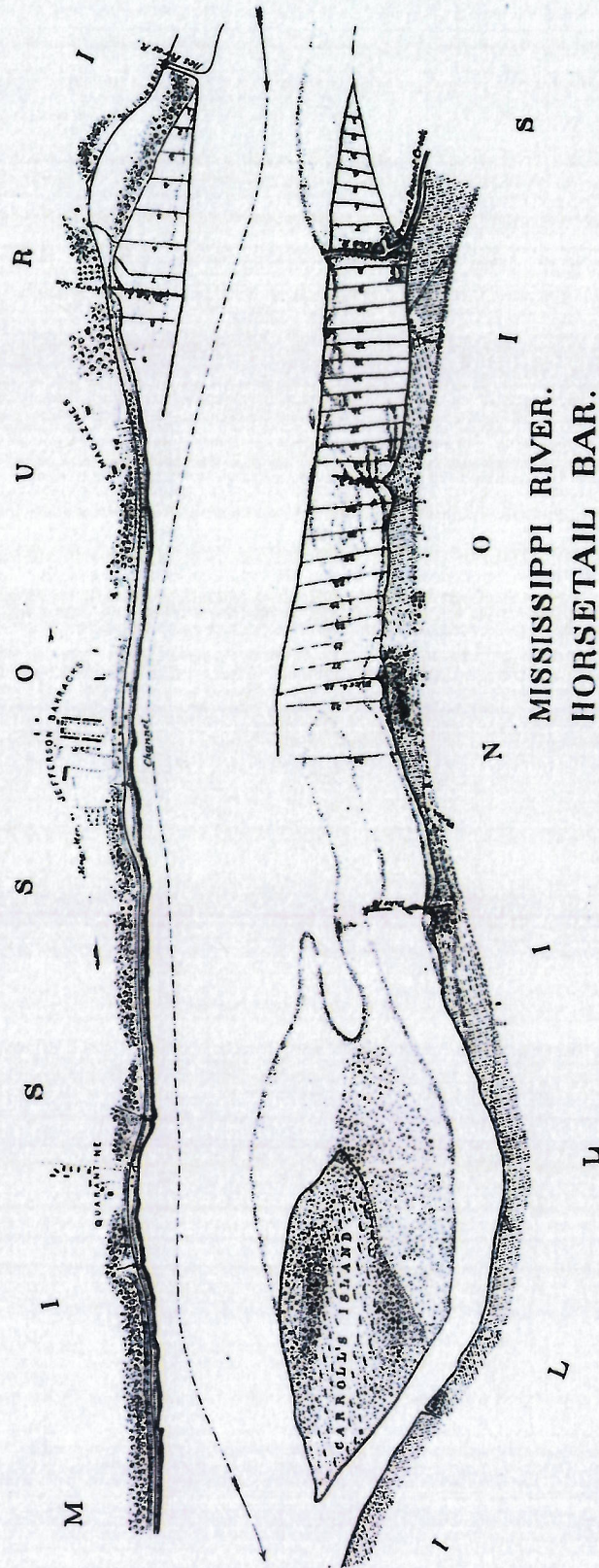
Scale of Feet.

Scale for Sections.

A R S E N A L I S L A N D

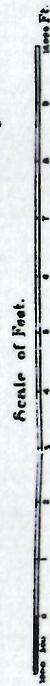


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Map showing location of works June 30th 1882.

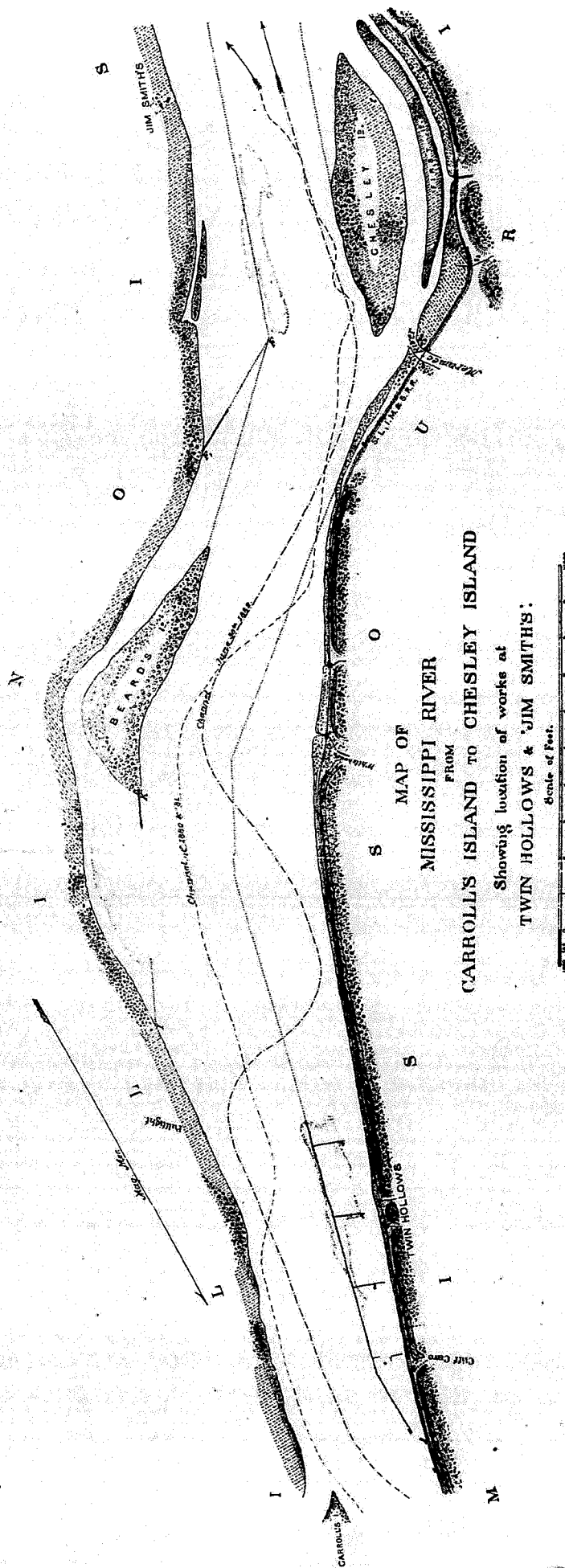
Bars are shown as they appear at a 15' stage.





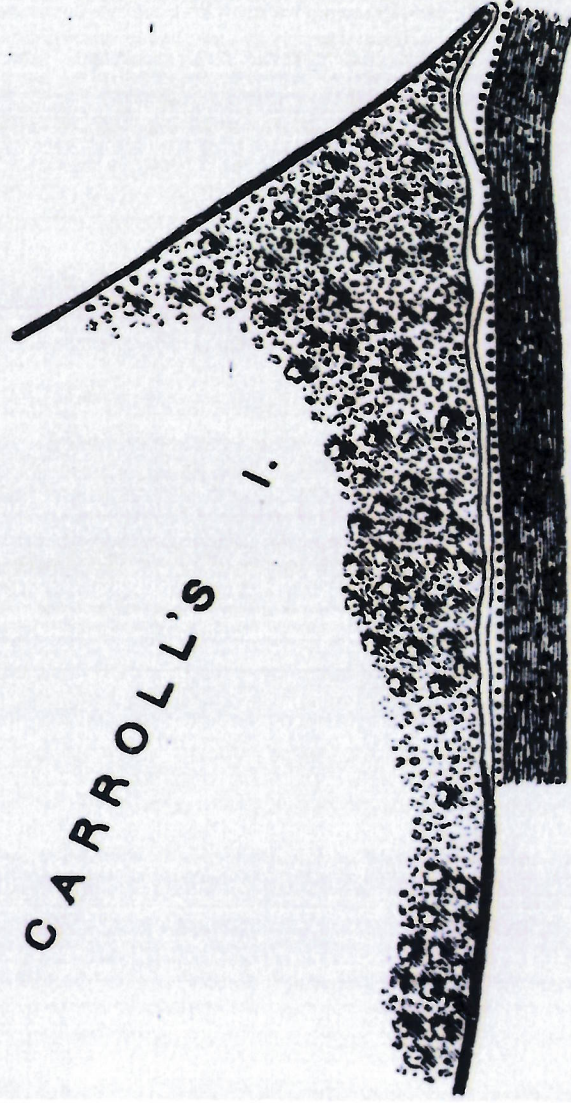
Scale of Feet.

2093



CARROLL'S ISLAND PROTECTION.

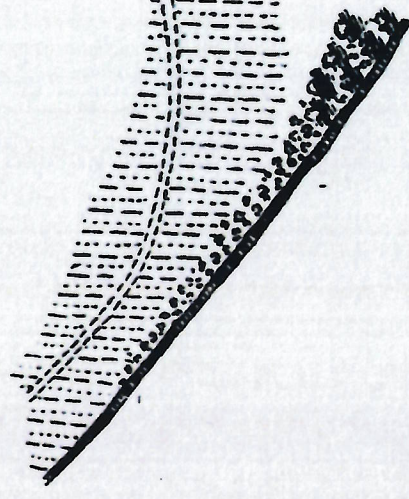
Scale of Feet.



CARROLL'S

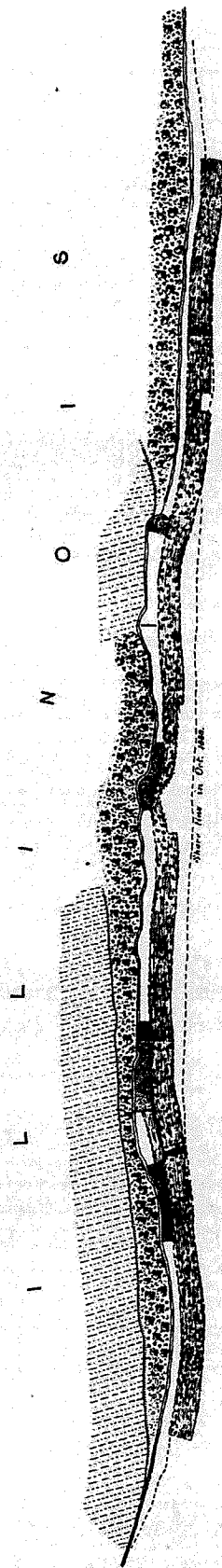
I.

MISSISSIPPI RIVER



TWIN HOLLOWS, EAST SIDE.
BANK PROTECTION.

Scale of Feet.

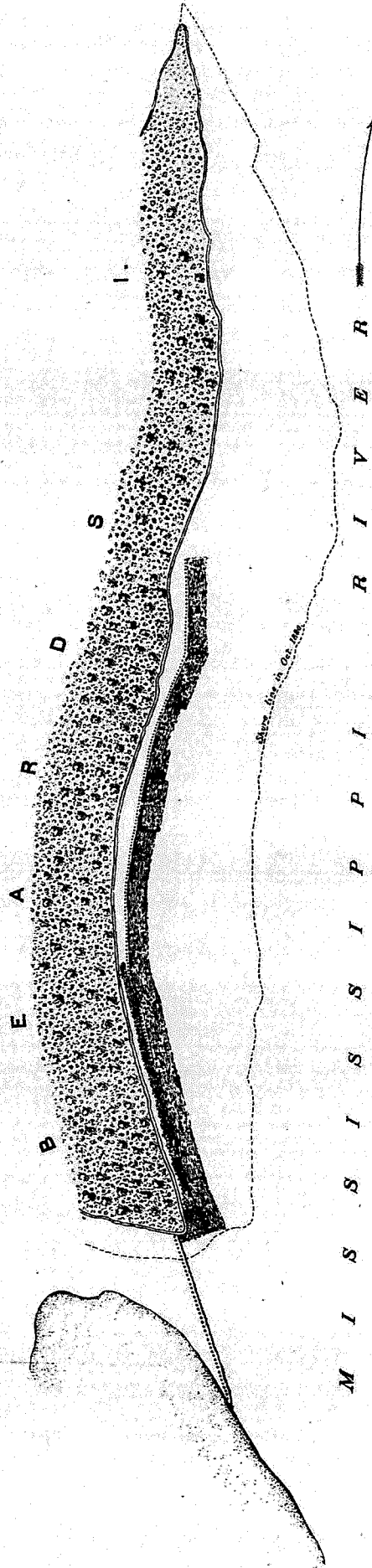


M I S S I S S I P P I , R I V E R

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BEARD'S ISLAND PROTECTION.

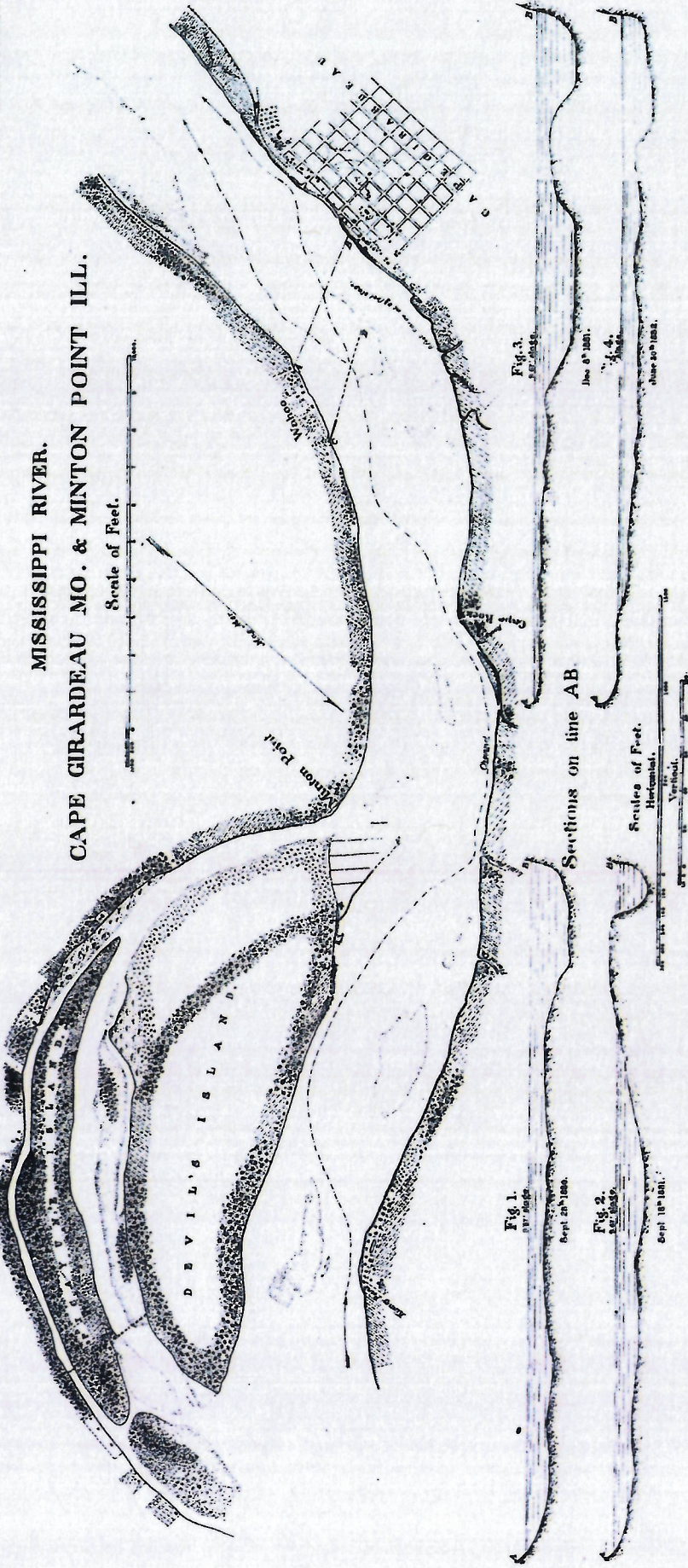
Scale of Feet.



(12)

MISSISSIPPI RIVER.
CAPE GIRARDEAU MO. & MINTON POINT ILL.

Scale of Feet.



of constructing and placing curtain, is shown on Plate V,* in which Figs. 1, 2, and 3 are respectively section, plan, and elevation. When the curtain has been constructed upon the whys it is launched bodily upon the water and floats against the piles. * * * The edge in contact with the piles is made fast to them, and a quarter-line stretched from the up-stream corner of the curtain to the hurdle. * * * This being done, men with pikes or hurdling-forks stand upon the barge and begin its sinking by bearing upon its up-stream edge. * * * The current striking the top surface of the curtain revolves it about its fixed edge into position. * * *

In this method of placing the curtain no stone is required for staking or securing it in position.

With the top edge fast to the piles, the bottom edge held from sliding along the hurdle by the quarter-line above referred to, and the constant force of the current acting as a lateral component to resist any tendency to move in that direction, the curtain could not or need not be more secure.

3. METHOD OF DRIVING PILES.

The pile-drivers used during the past year were of the pattern used at Horseshall Bar and other points. The piles driven during the year have been by jet and hammer combined, except in case of repairs, where the piles were driven through a footing mattress or drift-pile, rendering the jet impracticable when the hammer alone was used. But few instances of this kind have occurred, and have not been made distinct note of in connection with the statement below given.

PILES DRIVEN BY JET AND HAMMER.

Time, working hours	2, 635
Number of piles driven	2, 036
Average depth driven, feet.....	14.3
Number of piles driven per hour	0.77
Number of feet driven per hour	11.07

The above statement is given not as an example to be followed, but as a means of comparing work done in different localities and under entirely different circumstances.

The past year having been one noted for its unfavorable influences, any standard deduced from a single point of application would lead to an erroneous conclusion as to what could be done in other localities, or under different circumstances in the same locality.

4. PROGRESS MADE TOWARDS COMPLETING THE IMPROVEMENT.

Large deposits have been made during the year over the area reclaimed by the hurdles at Minton Point, aggregating 1,100,000 cubic yards.

In addition to this, large deposits have been made along the Illinois shore at Minton Point and below the primary hurdle opposite Cape Girardeau which cannot be estimated, but are as evidently the result of the work as are those lying within the hurdle area.

To show more clearly the changes which occurred immediately in front of the city of Cape Girardeau, four sections on the line A B were taken at different times, and are shown with all necessary facts in Figs. 1, 2, 3, and 4 on the map, Plate XX.

Very respectfully, your obedient servant,

J. A. WORTHEN,
Assistant Engineer.

Maj. O. H. ERNST,
Corps of Engineers, U. S. A.

* Plate omitted.