accommodate such a boat at the very lowest stage in any part of the river under consideration, viz, from the Big Island to the mouth. There are all the necessary conveniences for building this boat at Monroe, on the Ouachita River, but one day's run from the Saline River.

The monthly expenditure in operating such a boat would be—

Supervising engineer	$150
Mate	100
Cook and helper	60
Twenty laborers, at $40 per month	800
Subsistence for 24 men, at 50 cents per day	360
	1,470

ESTIMATE OF COST OF PROPOSED IMPROVEMENT OF SALINE RIVER FROM THE BIG ISLAND TO ITS MOUTH, 260 MILES.

Building light snagboat	$5,000
Flatboat for quarters, &c	800
Outfit of tools, 400; 25 per cent. for repairs	500
Removing snags and cutting timber, twelve months' work, at $470 per month	17,640
Clearing 27.5 miles, 30 feet wide, 100 acres, at $20	2,000
Add one month's passage down stream	1,470
Contingencies, 10 per cent	2,741
Total	30,151

COMMERCIAL STATISTICS.

The amount of commerce carried on during the six months ending January 31, 1879, on the Saline River, Arkansas, embraces—

Cotton, about 20,000 bales, valued at	$800,000
Staves, timber, &c., estimated	10,000
Hides, about 4,000 pounds, sundries, &c	2,000
Tobacco, about 15,000 pounds, valued at	2,000
Value of down freight	814,000
Return stores, supplies, estimated	500,000
Total	1,314,000

It is said by many cotton-growers and storekeepers along the stream, that if the navigation of the Saline River is improved, it will amount to over $2,000,000 per annum.

The river was navigated during good stages of water in the past six months by the steamers Willie and Acme, which made alternate trips, under one management, every ten days between Cavaness Landing and Trenton, La. These boats have each a carrying capacity of 500 bales of cotton.

The following is a list of the principal steamboat landings, and bales of cotton shipped from each:

Names.	Distance from mouth of river.	Bank.	Bales.	Names.	Distance from mouth of river.	Bank.	Bales.
	Miles.				*Miles.*		
Godfrey	22	Right.	400	Gee's	80.5	Left	400
Hamlett's	30	Left	400	Veasy's	86	Left	200
Baden Cut-off	42	Left	300	Osment's Bluff	92	Left	250
Hampton's	50	Right	1,000	White's	98	Left	200
Akan's Bluff	58	Left	100	Frazer's	106	Right.	600
Meek's	70	Right.	200	Sutton's	109	Right.	650
Long View	71	Left	2,000	Caveness	119	Left	3,000
Pugh's	71.5	Right.	100	Scobey	131	Right.	200
Carcoff	76.5	Right.	400	Mount Elba	159	Right.	5,000

Very respectfully, your obedient servant,

ZEPH HARRISON,
Civil Engineer.

Maj. W. H. H. BENYAURD,
Captain Corps of Engineers, U. S. A.

APPENDIX M.

REPORTS OF BOARD OF ENGINEERS ON IMPROVEMENT OF LOW-WATER NAVIGATION OF MISSISSIPPI AND MISSOURI RIVERS.

M 1.

IMPROVEMENT OF LOW-WATER NAVIGATION OF THE MISSISSIPPI RIVER BELOW CAIRO.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., January 28, 1879.

SIR: I beg leave to submit herewith a copy of the preliminary report of the Board of Engineers appointed to consider and report a plan for the improvement of the low-water navigation of the Mississippi River below the mouth of the Ohio River.

The general plan of improvement proposed by the Board is that of contracting the channel to an approximate low-water width of 3,500 feet by means of dikes of brush, &c., and where the bed of the river is found to be too hard to be worn away by the river-current, dredging, in addition to the reduction of width, to be resorted to.

The Board states that—

The main question is one of cost. Previous, then, to entering upon any general scheme of improvement involving an expenditure of many millions, this question should be settled in the only practicable way, by trial. * * *

That such a trial may thoroughly test the practicability and the cost of regulating the river and increasing its low-water depth, one of the worst places should be selected. Such a place is the Plum Point Reach, 160 miles below Cairo. This reach is about 20 miles in length, and presents in many places excessive width, reaching 2 miles at high-water and a mile and a half at low-water. * * *

Should experience show that works of a light character, such as hurdle work, brush ropes, and very light brush dikes, whose object is to make the river drop its sediment, thus building itself its contracting works, may be largely used, the Board still do not estimate the cost of obtaining 10 feet of water at low-water through this reach at less than $600,000. Should substantial dikes be required throughout, this cost may be tripled.

The Board, therefore, recommends in sum as follows:

1st. That an appropriation of $600,000 be asked for the improvement of the Plum Island Reach.

2d. That the improvement be effected by narrowing the shoal or wide portions of the low-water river to about 3,500 feet, and by protecting caving banks where necessary.

I concur in the recommendations of the Board, and respectfully suggest that the report be sent to the House of Representatives for the information of the Committee on Commerce.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. GEO. W. MCCRARY,
Secretary of War.

REPORT OF BOARD OF ENGINEERS.

NEW YORK CITY, *January* 25, 1879.

SIR: The Board of Engineers for the improvement of the low-water navigation of the Mississippi River below Cairo, constituted by Special Orders No. 71, Headquarters Corps of Engineers, Washington, D. C., July 8, 1878, have the honor to submit the following preliminary report:

1. The chief sources of information respecting this part of the river are the Report on the Physics and Hydraulics of the Mississippi River, by Humphreys and Abbot; Report on Mississippi River from Cairo to New Orleans, by Maj. C. R. Suter, in Report of Chief of Engineers for 1875; map of a reconnaissance of the Mississippi River, 1874, by Maj. C. R. Suter, Corps of Engineers, and reconnaissance of the Mississippi and Ohio Rivers, 1871, by Captains Young and Poussin, Topographical Engineers.

Existing maps are, save for small portions of the river, only reconnaissances, and there is little definite information to be obtained about the condition or position of the river fifty years ago, which might enable us to judge of future changes of the river by those of the past.

The survey of the river now being carried on under the Engineer Department will, when completed, furnish the precise condition of the river at a definite date, and thus give a standard to which all future changes may be referred, and by which they may be studied.

The Board examined in November, 1878, the river from Cairo to Lake Providence, a distance of 530 miles, which embraces the chief obstructions to navigation below Cairo. They have requested that detailed surveys may be made of several portions of the river where navigation is most usually obstructed, but it will be several months before the surveys can be completed.

In the absence of accurate maps, it is not possible to give detailed plans or precise estimates, but the general method of improvement to be followed can be indicated.

2. A brief description of this portion of the river, with some statistics taken from Humphreys's and Abbot's report, will give an idea of the magnitude of the work.

From Cairo to the Gulf of Mexico, a distance by the river of nearly 1,100 miles, the Mississippi flows in an alluvial plain subject to overflow at the highest stages of the river, the width of this plain averaging 30 or 40 miles. Numerous curved lakes, evidently once bends in the river and separated from it by cut-offs and subsequent silting up of their ends, are scattered along the banks. They are sometimes miles from the present river, thus indicating how unstable it is and how widely it has wandered.

A glance at the map shows that from Cairo to New Orleans the river is almost a continuous series of bends whose concave portions are alternately on the right and left banks of the river. The radius of the concave bend is rarely less than a mile, and a long bend is usually about 2 miles, sometimes, however, rising to 3 miles for bends of 180°.

This curvature of the river has great influence on the depth in the curved portion, the water next the concave bank being invariably deep when the thread of water of greatest velocity follows the concave bank at low river.

Descending the river at low-water one sees a succession of bends whose concave banks are followed by the steamer, the convex side of each bend usually having a sand-bar running far out from the high-water shore into the river.

Wooded islands of large area are frequently included between the arms of the river, and, when it is wide, sand-bars or sand islands, whose areas reach hundreds of acres, may fill the spaces between the high-water banks abandoned by the water. These bars have been called sand-bars, but layers of gravel are frequently found on them; at Cork's Point below the mouth of the Arkansas, such pebbles 3 inches in length were noticed. The material of the banks, where bluffs do not reach the river, is sand, sandy clay, and sometimes a little gravel. Many of the concave bends are receding under the action of the river, a recession of 300 feet a year not being extraordinary. On the left bank, bluffs reach or approach the river in many places; on the right bank, at but one.

The following data are from Humphreys's and Abbot's report:

Mean dimensions of cross-section between banks.

Locality.	High-water.			Low-water.		
	Area.	Width.	Maximum depth.	Area.	Width.	Maximum depth.
	Square feet.	*Feet.*	*Feet.*	*Square feet.*	*Feet.*	*Feet.*
Ohio River to Arkansas River	191, 000	4, 470	87	45, 000	3, 400	49
Arkansas River to Red River	199, 000	4, 080	96	54, 000	3, 060	56

The maximum range between high and low river at Cairo is 48.4 feet; at Memphis, 37.1 feet; at Vicksburg, 48.3 feet; at Natchez, 51.5 feet.

The high-water slope between Cairo and Columbus is 0.571 foot, and the low-water slope 0.381 foot per mile.

Between Natchez and Red River Landing the high-water slope is 0.266 foot per mile, and the low-water slope 0.158 foot. In 1858 the maximum river-discharge at Columbus, Ky., was 1,403,400 cubic feet per second, and the minimum 128,670 cubic feet.

In 1851–'52, at Carrollton, the maximum value of the ratio, by weight, of sediment to water carrying it, was $\frac{1}{681}$ in June, and the minimum value of this fraction was $\frac{1}{6383}$ in October, the mean for the year being $\frac{1}{1808}$.

At Columbus, in 1858, between March 15 and November 15, these fractions were $\frac{1}{670}$, $\frac{1}{7152}$, and $\frac{1}{1321}$, the mean for the year. At Columbus, in 1858, the highest mean velocity was 8.47 feet per second; on June 17, the highest observed velocity in any section, 11.1 feet. The lowest mean velocity was 1.50 feet on October 16.

At Vicksburg, in 1858, the highest mean velocity of the river was 7.04 feet on May 28, the maximum observed velocity in any section being 8.0 feet. The least mean velocity was 3.01 feet on October 25.

Such mean velocities as 8.47 feet or 7.04 feet per second are ample to give the river a powerful eroding action on the sand, which is so large a constituent of both bed and banks.

As the mean cross-section of the high-water river from the mouth of the Ohio River to the mouth of the Arkansas is 191,000 square feet, while the high-water cross-section at Columbus is only 166,200 square feet, the mean velocity at Columbus would exceed that at a point where the cross-section had its mean value by about one-eighth.

At Vicksburg the high-water cross-section is 179,500 square feet, while the mean cross-section of the high-water river between the mouths of the Arkansas and Red Rivers is 199,000 square feet.

The mean velocity of the high-water river where it had its mean cross-section near Vicksburg would then be about one-tenth less than at

Vicksburg. These reduced velocities are still ample for powerful action on the river bed and banks.

3. As it is the low-water condition of the river which specially interests navigation, that should be considered somewhat in detail.

In a river that rises 40 or 50 feet there is, of course, ample depth of water at the higher stages.

When the river falls these depths may diminish so much as, while leaving an ample depth of water in the concave bends, yet to give shoal water at those places where the stream crosses from a high-water concave bank on one side to a similar bank on the other side, provided the low-water width of the river at this place of crossing much exceeds the average low-water width.

It must be remembered that at these wide shoal places the river bed may have absolute elevations at the same place, differing by several feet at different stages of the river in the same year.

Col. J. H. Simpson (Report of Chief of Engineers, 1877) states that in 1876, at Horsetail Bar, below Saint Louis, after an unusually long high-water period, the bed of the river was filled with sand to the height of 10 feet above low-water mark. The same phenomenon in shoal places is generally well known to pilots.

The first difficulty at a shoal crossing may be found when the river is still from 6 to 10 feet above low-water. The deposit left by the falling river, which has filled up the low-water channels of the preceding year, acts as a low dam across the river. The river cuts its way down through this dam, and if its efforts are confined to a narrow width, may cut away the bottom as rapidly as the river surface falls, so that the river may possibly fall several feet below a stage already rather low without diminishing the depth of the water in the channel.

On the other hand, at one of these shoal crossings, the river may shift its channel several times during low-water, giving uncertain and dangerous navigation, or, not being sufficiently concentrated, may not have the power to cut a sufficient channel through the high-water deposit.

Ordinarily the shoal places are where the river, being wide, passes from a concave bend on one bank to another on the opposite bank; but shoal water may occur in the straight reach connecting two concave bends on the same bank, when this straight reach arises from the gradual filling up of a concave bend, as sometimes occurs. From an examination of the maps of the river, and from our knowledge of the depths of water and the position of shoal places, some conclusions can be drawn in general terms, which must be controlling in any system for the improvement of the low-water navigation of this portion of the river.

1st. There is ample depth of water at low river whenever the low-water width does not exceed about 3,500 feet.

2d. There is ample depth wherever the thread of the current follows a well-marked concave high-water bank.

3d. Low-water navigation may be bad in those reaches approximately straight which connect the deep pools under two concave banks, if the width of the low-water river in this reach largely exceeds 3,500 feet. (The width 3,500 feet is an approximation.)

There is another element which is of serious importance in the problem of improving the low-water navigation of the river, namely, its great instability.

The crescent-shaped lakes scattered through the alluvial plain have already been referred to. The most distant points of some of them are now 6 or 8 miles from the river, showing that within a period so recent that the sediment derived from the river-overflows has not had time to fill them up, the river has changed its position by such amounts.

Again, in many of the bends the river is rapidly cutting into the concave banks while the opposite points are extending, the river thus moving laterally with its moving banks.

The high-water velocities are ample for acting powerfully on the banks, but in some cases this eroding or caving appears to be largely accelerated by another action. This latter seems to arise from the river-water penetrating sand strata to a considerable distance from the river-banks, and returning to the river, perhaps with a considerable head when the river falls, carrying the sand strata with it, thus allowing the overlying masses to fall into the river. Caving at the rate of 200 or 300 feet a year is not unusual, and these amounts are sometimes much exceeded. All the materials is carried downstream, some to the points or shoals immediately below, some to uncertain distances. This moving of material from one point to another is injurious to the condition of the river.

The report of Maj. C. R. Suter, Corps of Engineers, in the Report of Chief of Engineers for 1875, states that there are forty-three places between Cairo and the mouth of the Red River where low-water depths of less than 10 feet, and thirteen where low-water depths of less than 5 feet may be found. The aggregate length of these shoal places is about 150 miles. Reference may be had to that report for detailed information respecting the river in this connection.

4. Transportation on the river was formerly by flat-boats and steamboats, but of late years this system has been partially replaced, especially for grain and coal, by the system of barges towed by steamboats. These barges carry from 600 to 1,500 tons each, and from three to five of them are towed by a single steamer. Their draft, loaded, rarely exceeds 8 feet.

Large steamboats are sometimes loaded to about 12 feet, when the stage of the river and depth of water on the bars allow it. If 10 feet of water could be secured at low river from Saint Louis to New Orleans, it would probably satisfy all demands; and if the improvement of the river is undertaken that depth should be aimed at.

From a report of Hon. E. O. Stannard, Chairman, dated October 30, 1873, to Senate Committee on Transportation, it appears that, from 1864 to 1872, inclusive, there were on an average fifty-two days on which the least depth of water between Saint Louis and Cairo was less than 6 feet, and sixty-nine days in which it was less than 10 feet. These numbers would probably be somewhat less for the river from Cairo to New Orleans.

The time of low-water is usually October or November, and it is for this low-water period that the improvement is needed.

It is scarcely necessary to speak of the magnitude of the interests involved in the improvement of a river draining a valley so enormous, so fertile, and so populous as that of the Mississippi.

The Hon. Mr. Stannard, in the paper already referred to, estimates the annual saving in transportation on grain alone, if the river were improved, at $28,000,000. While this may be an overestimate, it will yet be noticed that if a saving of one-tenth of this amount could be effected it would justify an expenditure of $70,000,000 to obtain it.

5. Having considered in general terms the present condition of the river and its navigation, and the needs of navigation in the future, the question of method of improvement remains to be examined. It has already been stated that where from local circumstances the low-water width of the river is only about 3,500 feet there is now ample depth at low-water.

If, then, where the river is now wide and shoal it can be aided to take a less width, a greater depth may be expected to result, provided the bed of the river at these shoal places is not too hard to be worn away by the river-current. The exact character of the river-bed can only be determined by numerous borings, some of which have already been undertaken at the request of the board, but the fact that deep water is found in all well-marked bends, and that this is true even where the river comes in contact with material which it has not itself deposited, as at the bluffs of Columbus and Memphis, seems to indicate that the river generally has the ability to scour out its bed. Should local exceptions to this rule be found, dredging, in addition to reduction of width, may be necessary, the reduction in width keeping the channel open when once formed.

Closure of "chutes" (so called) or high-water channels across the low elongated points which follow up the receding bends may be necessary, especially when these minor channels remain open at low-water.

As the shoals are ordinarily at points where the river, being wide, crosses at low-water from one bank to the other, those are the places at which greater depth of water is needed, and here works to narrow the low-water river will often be required on both sides.

The object of these works is simply to give to the low-water river the form which it has given to itself where the navigation is good. They should give to the low-water channel a curvature like that on the river which does not produce much caving, and in straight reaches a low-water width of about 3,500 feet. They must, when exposed to attack, be of sufficient strength to resist, of sufficient extent that the high river may not cut a new channel between them and the high-water banks, and their heights must be such that while interfering as little as possible with the high-water river, they shall yet direct the water of the river into the low-water channel before its depth falls to 10 feet.

The heights of these works and their character will vary with the different localities.

At a place where the river is already on the point of building up a shoal, or narrowing its low-water width, works of the slightest construction may produce great changes. On the other hand, should it be necessary at any place to bar against the river a route which the forces in operation strongly tend to make it take, costly constructions will be required to make the barring good.

Where slighter works are insufficient, recourse must be had to substantial dikes of brush and stone or gravel (like those ordinarily used in this country and in Europe) for closing low-water chutes and for building out the low-water banks to their assigned positions.

The directions of these dikes will vary from transverse to longitudinal in different places, and should, as far as possible, be executed in such order that those lower down stream may be erected on the deposit caused by those above. Where prejudicial scour of shoals or banks is produced, they must be protected by mattresses.

6. Experience elsewhere has shown that, by the use of the substantial dikes spoken of, the Mississippi can, with little doubt, be controlled.

The question is not mainly of the power of control, but of the cost of control.

No case is known of an attempt to regulate a river of the size of the Mississippi in order to improve its navigation. On a much smaller scale it has been done on the Vistula, near Culm, in Prussia. This stream at Culm has a discharge, both at high and low water, of about one-seventh that of the Mississippi at Columbus. Its high-water is about 22 feet (sometimes reaching 30 feet when obstructed by ice) above its low-water.

Formerly, near Culm, it had many arms separated by islands; was of irregular width, and had 1.5 feet of water in it at low river. It was improved by closing its chutes or lateral arms, and by substantial works on one or both shores, which limited its low-water width to 1,235 feet, and gave its channel a regular form. Its low-water depth has been increased by the works which are not yet complete to 4.1 feet. For portions where many latteral arms had to be closed the improvements cost $50,000 per mile, other portions costing $30,000 per mile.

In the absence of detailed surveys of the shoalest places in the river, it is impracticable to make anything more than rough estimates of the cost, and indeed the river is so changeable that any detailed plans might have to be entirely changed before their execution could be completed.

But if substantial dikes like those already used in similar improvements should prove necessary, the cost of such work, thoroughly controlling the river, may for considerable distances exceed $100,000 per mile. The Board, however, hopes that in many places much lighter structures may be used, both to induce silting and to retain the land once gained to form the new bank of the low-water river.

Experiments in India, and on the Missouri River by Major Suter, show that great silting may sometimes be produced by very inexpensive means, and when the work of improvement at any place on the Mississippi River is begun every form of experiment should be tried that promises to reduce the cost.

Thus far, reference has only been had to works needed to increase the depth of water across shoal places. But it has been already stated that many banks are caving rapidly, thus giving rise to shiftings in the position of the river and throwing into it large amounts of material to be again deposited below. Protection of caving banks will therefore be needed to a distance above any improvement sufficient to remove any danger of the river abandoning the route assigned to its low-water channel or of damaging the works by getting in their rear.

To thoroughly regulate the river, caving, even in those bends which have deep water on the crossings below them, should be stopped, in order that the river may not so change its position as to give bad water where there is now good water, and to avoid the danger of shoals being produced below by the material moved.

The protection of these caving banks can be effected by mattresses; where the water is very deep it will be expensive, but as this protection where the water is now deep gives no immediate aid to navigation, its consideration can be delayed till the experience gained at the shoal places in the river demonstrates its necessity and shows how light constructions can be safely used.

7. The Board has already stated that the main question is one of cost. Previous, then, to entering on any general scheme of improvement involving an expenditure of many millions, this question should be settled in the only practical way—by trial. Should that trial show that constructions like those generally used in Europe and this country are necessary, Congress can then decide whether the results to be gained will justify the cost.

If, on the other hand, it is found that the cost of construction can be largely reduced, the advisability of the improvement becomes still stronger.

That such a trial may thoroughly test the practicability and the cost of regulating the river and increasing its low-water depth, one of the worst places on the river should be selected. Such a place is the Plum Point Reach, 160 miles below Cairo. This reach is about 20 miles in