APPENDIX S S.

MISSISSIPPI RIVER COMMISSION.

PRELIMINARY REPORT.*

THE MISSISSIPPI RIVER COMMISSION,
PRESIDENT'S OFFICE, ARMY BUILDING,
33 WEST HOUSTON STREET,
New York, March 6, 1880.

SIR: I have the honor to transmit herewith a preliminary or partial report of the Mississippi River Commission. It is expected that the two members of the Commission—General Comstock and Mr. Harrison—who have withheld their signatures from the report will submit separate statements, embodying individual dissenting opinions, upon the several subjects discussed therein. When these are received they will be forwarded without delay, in order that they may take their appropriate place as appendixes to the report.

The following papers are hereunto appended, viz:

1. A financial statement made by Lieut. Smith S. Leach, Corps of Engineers, the disbursing officer of the Commission, showing the disbursements made and liabilities incurred to February 16, 1880. It will be seen from the statement that the whole amount appropriated will be expended by the close of the current fiscal year in making the surveys and examinations deemed requisite by the Commission.

2. A Coast Survey chart of the "Mississippi River from the Passes to Grand Prairie, Louisiana."

It is understood from the Superintendent of the Coast and Geodetic Survey that the engraved plate of this chart will be placed at the disposal of the Public Printer, so that its reproduction will be unnecessary.

Very respectfully, your obedient servant,

Q. A. GILLMORE,
Lieutenant-Colonel of Engineers, Bvt. Maj. Gen., U. S. A.,
President Mississippi River Commission.

Hon. ALEXANDER RAMSEY,
Secretary of War, Washington, D. C.

[Indorsement.]

OFFICE CHIEF OF ENGINEERS, U. S. ARMY,
March 8, 1880.

Respectfully forwarded to the honorable the Secretary of War.

H. G. WRIGHT,
Chief of Engineers,
Brig. & Bvt. Maj. Gen.

*H. R. Ex. Doc. No. 58, 46 Cong., 2d sess.

REPORT.

WASHINGTON, D. C., *February* 17, 1880.

SIR: The Mississippi River Commission, constituted under an act of Congress approved June 28, 1879, respectfully submit the following partial report:

The work assigned to the Commission was—

First. To direct and complete such surveys of the Mississippi River between the Head of the Passes, near its mouth and its headwaters, as were then in progress; and to make such additional surveys and examinations of said river and its tributaries as might by it be deemed necessary.

Second. To take into consideration and mature such plan or plans as will correct, permanently locate, and deepen the channel, and protect the banks of the Mississippi River; improve and give safety and ease to the navigation thereof; prevent destructive floods and promote and facilitate commerce and the postal service; and with such plans to prepare and submit estimates of the cost of executing the work.

Third. To report specifically upon the practicability, feasibility, and probable cost of the plans known as the jetty system, the levee system, and the outlet system.

By section 5 of the act authority was given to the Commission, prior to the completion of all the surveys and examinations, to prepare and submit plans and estimates of cost for such immediate works as in the judgment of the commission may constitute a part of the general system of works contemplated.

The Commission met for organization in the city of Washington on the 19th day of August, all the members being present, and immediately upon its organization took into consideration the surveys of the river already "*in progress*" and "*such additional surveys, examinations*, and *investigations, topographical, hydrographical*, and *hydrometrical*," as seemed necessary to carry out the objects of the act of Congress establishing the Commission.

It was found that the portion of the river lying above the mouth of the Ohio had been essentially covered by the several shore-line surveys already completed, or drawing to a close, so that the attention of the Commission was directed more especially to the lower river between Cairo and the Head of the Passes. This portion of the river, measuring about 1,100 miles along the channel, had been the scene of numerous detached surveys, the data from which will be available notwithstanding the intervals of time that they cover; and in providing for the connection and extension of these, the Commission decided to so arrange the work of the present fiscal year that the information immediately required should be obtained by systematic methods, useful not only to the proximate ends in view, but in connection with the wider range of inquiry that must ultimately be necessary.

It was considered important that the triangulation, so essential in locating the river, however limited the field of practical operations of immediate improvement might be, should be so executed and permanently marked that it would furnish the basis of future surveys.

It was therefore decided that a line of secondary triangulation should be run, its triangles closing within 6 seconds.

For the present, however, it was deemed desirable to execute no detailed or widely extended topography, but to develop as rapidly as possible the shore lines and the forms of the river bed.

It was furthermore decided that physical inquiries extending to all

the recognized phenomena likely to have a bearing upon problems of improvement should be instituted at once, and that they should be based upon the experience of predecessors who had already made much progress in these studies.

Provision was made for running lines of precise levels along the river bank and for maintaining and increasing the number of the stations at which the elevations of the river are recorded, so as to trace in future the progress of floods and the larger features of the river slopes, without, it is hoped, any further interruption.

Provision was also made for physical examinations of selected reaches of the river, distant from each other, but presenting locally and relatively the most widely-contrasted elements of width, depth, and curvature; that the conditions most favorable and those most inimical to navigation might thus be traced back to their causes inductively.

At these early meetings resolutions were adopted embodying the sense of the Commission as to the extent and character of the surveys required, and the committee composed of a majority of the members was appointed to carry out the views thus recorded.

Inquiries were made of the Secretary of War and of the Secretary of the Treasury as to the aid they could render in these surveys, free of expense to this Commission, and the committee on surveys was authorized, after the receipt of replies to the above inquiries, to direct the secretary of the Commission to employ the necessary persons, and make all purchases of instruments, materials, and outfit needed to carry out the provisions of the resolutions already adopted as to surveys, &c., to be made at once.

The surveys thus instituted are being executed under direction of this Commission, in part by its employés and in part by parties and vessels of the Coast and Geodetic Survey, detailed under section 3 of the act; the former moving from Cairo southward, the latter working in the lower part of the river.

The continual prevalence of yellow fever at several points on the lower river until late in the fall prevented these parties from beginning their work as soon as was expected.

The following estimates of the extent of river completed or likely to be covered during the present season are based upon the rate of progress furnished in the schedule drawn up by the Secretary of the Commission, and in the report of the Superintendent of the Coast and Geodetic Survey.

Gauges.—The gauges along the river between Cairo and New Orleans were increased in number to 20, and more recently others have been added between Cairo and Saint Louis, so that the elevations of the river surface are now recorded daily at intervals of about 50 miles.

The zeroes of these gauges are to be referred to a common plane of reference by the lines of precise levels to be described hereafter in the order of progress.

Triangulation.—Of the 1,100 miles of river lying between Cairo and the Head of the Passes, the triangulation of past years, executed by the government, amounted in all to about 407 miles, comprising the progress work of the Coast and Geodetic Survey as well as the surveys made by the United States Corps of Engineers.

Of the employés of the Commission, three double parties, now in the field, are engaged upon triangulation. This work, inclusive of about 18 miles previously executed, has already reached Memphis; and, as below this point about 85 miles of work previously executed will be met with,

it is anticipated that the parties will reach the mouth of White River, 420 miles below Cairo, by the 1st of April.

The trigonometrical points established by these parties are to be referred to permanent marks beyond the erosions of the river, by the topographical party following them.

Four single triangulation parties have been placed on the river, under this Commission, by the Superintendent of the Coast and Geodetic Survey, Mr. C. P. Patterson; and these have been located by the Board with a view to connect the isolated fields of work which now rest upon separate bases.

Mr. Patterson expects, with the appropriation made by Congress for the work under his superintendence, together with an allotment from the funds of this Commission, to execute 300 miles of triangulation during the present fiscal year, and make the chain of geographical positions complete from the Gulf of Mexico to Providence, about 500 miles.

As these parties were not to be immediately followed by topographical surveyors, it was deemed advisable to require of them the establishment of reference marks, which has rendered their progress slower than it otherwise would have been.

At the request of the Commission, the Superintendent of the Coast and Geodetic Survey has measured a base line in the vicinity of Cottonwood Point, 120 miles below Cairo, to be used in connection with the triangulation executed by the employés of the board.

Topography and hydrography.—These have been combined in the operations of one party, having three divisions, composed of employés of the Commission. One of these divisions develops the shore line of the actual river with its banks, tow-heads, chutes, islands, &c., as well as levees when not more than a half mile back from the water; another follows with levels, giving the elevations of banks, water-surfaces, cross-sections of levees, &c.; while the third division sounds out the bed of the stream in connection with the levelings, so as to complete the normal cross-sections of the river and its approaches about every half mile. All this work rests upon the preceding triangulation, and the topographers, as they pass the triangulation stations, are required to refer them to permanent marks already mentioned. These marks are placed about three miles apart, measured along the general course of the river, and in pairs on either side, the one nearest the river bank being so placed as to be sure to remain undisturbed for at least twenty years.

The present work will not furnish a detailed map showing the character and elevation of the swamp and bottom lands lying far back from the actual lines of the river, but the necessity of more elaborate maps is anticipated, and these marks are to secure the full advantage of all triangulation executed this season as the basis of future topographical work wherever the trigonometrical points shall have been obliterated by the caving of the banks. This combined party, traversing shore lines, measuring elevations, and sounding out cross-sections, has advanced 160 miles and made connection with the work of examination party in the vicinity of Plum Point. It is anticipated that it will carry its work to Memphis during the present season; beyond this, for a distance of 40 miles, complete maps exist from the survey made by General Comstock before the Commission was created.

At the time the Commission was organized charts had been published by the Coast and Geodetic Survey of the portion of the river lying between Point Houma (about 72 miles above New Orleans and the Gulf), showing depths of water with marginal topography; so that there re-

mained for this Commission to execute, in the river below Cairo, about 900 miles of surveys of the skeleton form above indicated.

Precise levels.—From employés of the Commission two parties were assigned to run a line of precise levels, in duplicate, and in opposite directions, with permanent bench-marks every three miles, so located and marked that they may be relied upon for at least twenty years. The most accurate instruments known to engineers were placed in the hands of these parties, and they were instructed that the discrepancy in duplicate lines of levels should not exceed 5^{mm}, $\times$ the square root of the distance in kilometers.

They began their work at Columbus, 20 miles below Cairo, at the termination of a series of levels previously executed by General Comstock, and have advanced to Cottonwood Point, 120 miles below Cairo. They will probably reach Memphis by the middle of April, should no interruption from floods occur. Here they will connect again with a series of levels executed by General Comstock which extends about 83 miles below.

It is proposed to put another leveling party into the field as soon as proper instruments are obtained, and if this additional party can pursue its work until the first of May the precise levels will be brought nearly to the mouth of White River, where the triangulation of this season will probably terminate, as above stated.

In the lower portion of the river two parties of the Coast and Geodetic Survey are running similar lines of precise levels between Carrollton and Greenville, and the superintendent expects to be able to keep this work in progress during the entire season and close this space of 500 miles by the end of the fiscal year.

Examinations.—Three localities have been selected at which surveys are repeated frequently to ascertain the varying relations of the river and its bed; these are Plum Point and its approaches, Lake Providence and its neighborhood, and Carrollton; the last named being selected because it was the site of similar inquiries during the surveys of Humphreys and Abbot in 1858.

The observations at these places comprise the changes in the figure of the river bed at different stages of the water, the kind of material forming or moving along the bed, the figure and movements of sand-waves, the slope of water surface, the discharge, and the transverse curves of velocity.

The parties engaged in these physical surveys are employés of the Commission, many of whom had previously been engaged in similar studies. They commenced work in the low-river season, and it is hoped that the funds available will enable them to continue till the spring floods have subsided.

Borings.—A boring party has been organized to determine the depth of the alluvial deposits and the character of underlying strata in portions of the river requiring improvement. These borings have been finished in the vicinity of Memphis and Helena, and others are to be made at Choctaw Bend and other points.

SURVEYS AND EXPENSES OF COMMISSION.

It is necessary that the surveys and examinations which have been undertaken by the Commission and are now in progress below Cairo, under the authority conferred in section 3 of the act, should be continued, and that surveys should be commenced above Cairo, so far as they may be considered necessary for the advantageous progress of works of im-

provement. For these purposes and for salaries, mileage, traveling and office expenses of the Commission, there will be required during the coming fiscal year the sum of $200,000.

In view of the prospect of an extreme flood on the Lower Mississippi, which would afford an unusual opportunity for observations upon the operations of floods, the importance of an early appropriation of the amount estimated for surveys under the Commission is earnestly represented, in order that the system of observations already inaugurated may be made continuous through the flood season.

SYSTEMS OF IMPROVEMENT.

This Commission is not prepared, nor is it deemed necessary at the present time, to submit a full and detailed report, with estimates of final cost, upon any general system of river improvement. It seems proper, however, that all the several methods and plans embraced by the comprehensive and distinctive language used in the act, so far as they apply to or have direct bearing upon any of the objects contemplated therein, should be defined, and that the general principles which have been kept in view in adopting a plan which will concentrate rather than disperse the waters of the river, as the principal agent in securing the needed improvement in its navigation, should be briefly stated.

Whatever seems needful to be said upon the "outlet system," which, being one of diffusion and waste and not of concentration, does not commend itself to the judgment of the Commission, will be embodied in this report.

The Mississippi River, aside from its great length and other elements of wonderful and impressive magnitude, and the energy with which it maintains its tortuous and everchanging route to the sea, ranging over a broad alluvial region of its own creation, does not appear to be characterized by any phenomena peculiar to itself, or by any physical features not found in greater or less degree in other turbid streams flowing through alluvial deposits. Its waters within the limits of the alluvial district constantly carry large, although very variable, quantities of sedimentary matter. This sediment, or silt, derived from tributary streams, from caving banks, and from its own bed by erosion and scour, is borne along by the current in such manner that a large part of it is held in more or less constant suspension in the water, while a portion is rolled or swept along upon the bottom.

An exact relation between the quantity of silt transported or moved along by a stream, and the longitudinal velocity of its current, has not been discovered. Longitudinal velocity, however, is always accompanied by motion in other directions. Without upward motion of the water, there can be no continued suspension of sedimentary matter in it.

When, on any given reach of the same stream, the velocity, as usually measured by meters or floats, is increased, the vertical motion, and therefore the silt sustaining the transporting power of the stream, is also increased. It does not follow from this, however, that in different silt-bearing streams, or in different reaches of the same stream, or even in the same reach through varying stages of water or different seasons of the year, the same velocity of current invariably sustains and transports the same amount or proportion of sedimentary matter. No fixed relation has been discovered between a volume of water and the amount of sediment in it for any given observed velocity. The supply of earthy matter is very irregular, varying greatly, irrespective of changes of ve-

locity, with fluctuations in the stage of river, the relative discharge of different tributaries, the seasons of the year, the conditions governing rainfall, alternations of freezing and thawing, the kind of crops cultivated in the vicinity, and other causes.

Any reduction of velocity by lessening the sustaining and transporting power of the water, and by arresting some of the heavier particles which the diminished current is unable to move along upon the bottom, will tend to cause a deposit of solid earthy matter and raise the bed of the stream. The direct effect of raising the bed is to raise the surface slope. The surface slope may also be increased by reduction of the river's length by cut-offs and other causes.

Conversely, if the velocity be increased from any cause, a greater amount of silt will be thrown into suspension, which will be supplied by erosion. A lowering of both the bed of the stream and the surface slope will therefore ensue.

These general principles may be briefly and comprehensively stated as follows, viz: If the normal volume of water in a silt-bearing stream flowing in an alluvial bed of its own formation be permanently increased, there will result an increase of velocity, and consequently of erosion and silt-bearing power, an increase in area of average cross-section, and an ultimate lowering of the surface slope; and, conversely, if the normal flow be decreased in volume, there will ensue a decrease of velocity, silt-transporting power, and mean sectional area, and an ultimate raising of the surface slope.

THE OUTLET SYSTEM.

It has been supposed by many persons that, because the immediate effect of a crevasse during a flood is the reduction of the height of the river's surface in the vicinity of the crevasse and below it, lateral outlets, either natural or artificial, by which the flood-waters of the river are drawn off and conveyed through a shorter route to the sea, tend to prevent the recurrence of destructive floods, by supplying additional avenues for their escape. This method would undoubtedly be effective if the flood-waters of the Mississippi were not highly charged with sedimentary matters, which are held in suspension in the water by the current. To support this immense mass of earth and sand in suspension, and thus insure its transportation to the Gulf, the velocity of the current must be sustained. Without stopping to determine, or even discuss, the character of the relation which exists between the various velocities of current and the proportionate quantities of sediment which such velocities are capable of carrying in suspension, the fact seems to be established that when the current is checked in its natural flow during floods, a deposit of sediment will occur. Shoals are found in the river immediately below crevasses, which it is difficult to refer to any other cause than the loss of current velocity which takes place below the crevasse. As a portion of the volume of the river is drawn off by the crevasse when it is first made, it is impossible that the current below the crevasse can then be as rapid as it was before its occurrence. Being less rapid, it is unable to sustain the whole quantity of matter held in suspension by the more rapid current above the outlet, and consequently its surplus sediment falls to the bottom below the crevasse. This deposition continues until the size of the river below the crevasse has been so reduced by the shoaling that the current is again restored through the short distance in which the bottom of the river has been thus raised and the channel diminished. If the crevasse remained open, however, for sev-

eral years, it is evident that the shoal will continue to extend down the stream, for the reduced velocity will still exist in the river below the shoal. If the crevasse be kept open indefinitely, the shoaling will continue to extend down the stream until certain other injurious effects are produced, which will be presently referred to.

It is a well established law of hydraulics that the ratio of frictional resistance per unit of volume increases if the sectional area be diminished. Thus, if the volume of the river were suddenly divided by an island into two channels, the water flowing in them would encounter more frictional resistance than it met with while flowing in a single channel. Hence the currents through these channels would be more sluggish. As the water is charged with sediment the sluggish current would cause a deposit in the channels which would first begin at their upper ends, and would continue until the bottoms of the two channels would be so steepened that the current would attain a velocity capable of carrying the suspended sediment through them without further deposit. If the two channels were of nearly equal length and size, they would probably remain permanent, and the slope of the river's surface in flood time would be found to be steeper through them than above and below, where the volume flows in a single channel. If one of the two channels were materially longer than the other, the effort of the river to increase the steepness of the longer channel would be abortive, because its slope would be controlled by the shorter one. A shoal in the upper end of the long channel would, however, be built up to such height by the depositing action of the sluggish water in it, as finally to shut it off altogether from any connection with the river, while the still water at the lower end of such channel would promote the deposition of sediment at that end to such an extent as to build it up also, and thus completely separate the long channel from the main body of the river; in the mean time the shorter channel would have enlarged so as to accommodate the entire river. The longer channel would, in this event, constitute a lake, like one of the many lakes which are seen on a map of the alluvial basin of the river. Being removed from the influence of overflows, these lakes remain deep and clear for many centuries. The phenomenon just described invariably accompanies the formation of a cut-off. When one of these occurs, the volume of the river is at first divided into two channels of unequal length, an island being left between them.

In the case of a crevasse an island is also formed, having the main body of the river on the one side of it, and the crevasse channel on the other side. As the volume flowing in the main channel below a crevasse has been decreased by the amount drawn off through it, a steeper slope in the main river, if the crevasse be kept permanently open, becomes inevitable; because the shoal below the outlet, as it grows in length down stream from the deposition of successive floods, gradually increases the frictional resistance of the volume flowing through that diminished channel, and this tends to check the current of the river above the crevasse, and thus the shoaling of the river bed and the raising of the flood line *above* the site of the outlet ensue as a secondary and *permanent* effect.

It is in this way that silt-bearing streams flowing through alluvial deposits have the ability to increase or steepen their surface slopes, and thus recover the velocity of their currents and adjust them to the work of transporting the sedimentary matter with which the flood-waters are charged so that this matter may be carried without loss or gain. In proof of the correctness of these views, and of their full accordance with

well established hydraulic laws, we have the evidence of this relation between slope and volume presented in the phenomena of silt-bearing streams all over the world. Wherever such streams flow through alluvial deposits, other conditions being the same, the slope is least where the volume is greatest; and, conversely, the slope is found to be invariably increased as the volume is diminished. The Mississippi throughout its alluvial basin, not only in its main trunk, but in all of its outlets, presents no exception to this peculiar feature. Among numerous illustrations of this law the following examples may be cited:

The fall of the Atchafalaya is about six inches per mile from its head to the Gulf level, while the fall of the Mississippi from the same point is less than two inches per mile. The volume of the Atchafalaya is only about one-twelfth as great as that of the Mississippi where they separate. The fall of the South Pass is three inches per mile, whilst that of the Southwest Pass is but two inches per mile. The volume of the South Pass is only about one-quarter as large as that of the Southwest Pass.

As water selects the line of least resistance in flowing from a higher to a lower level, it follows that, inasmuch as that portion of the Mississippi floods which enters the Atchafalaya seeks the Gulf level through a route not half so long as that which follows the main river, and as it has a descent threefold greater than the portion that flows in the main river, the resistance in the shorter and steeper route of the Atchafalaya must be so much greater that these elements which tend to increase the current are so far neutralized as to produce in both routes to the sea that rate of current which is capable of transporting the sediment without loss or gain to the Gulf level, and thus a condition of equilibrium is established between these two routes to the sea. It seems unnecessary to state that the ratio of frictional resistance to volume of water resulting from the smaller size of the Atchafalaya is so much greater than that in the main river, that this condition of equilibrium or regimen of the two channels is the result. Anything which will tend to increase the flow permanently through either route would, if unchecked, have a tendency to cause the entire river to find its way ultimately through that route to the sea by lessening in it, as it enlarged, the ratio of frictional resistance to volume of water flowing in it. The subdelta-building ability of the smaller passes by which they prolong their length and thus flatten their slopes, will invariably tend to cause their extinction by results similar to those hereinafter referred to at Cubitt's Gap, the Jump, and the extinct outlets below them. This cause has tended to the extinction of many well-known bayous below the Atchafalaya. That the Atchafalaya remained so long unaltered, and is now evidently enlarging, is owing to important changes in a bed of the Mississippi near it, by which a large portion of the floods of Red River have been recently discharged through it.

This explanation of the relation between slope and volume is, of course, applicable to the other existing outlets referred to in this connection. For this reason the Commission believes that no surer method of ultimately raising the flood surface of the river can be adopted than by making lateral outlets for the escape of its flood waters. The raising of the flood surface necessitates an increase in the height of the levees and leaves shallower channels for navigation.

As the system of improvement proposed by the Commission is based upon a conservation of the flood waters of the river, and their concentration into one channel of an approximately uniform width, it would seem scarcely necessary further to consider a system based upon theo-

ries and arguments so diametrically opposed to it as the outlet system is thus shown to be.

Allusion has only been made so far to phenomena attending long-established or permanent outlets. A proposition to "provide for improving the navigation of the Mississippi River and for the reclamation of the low lands of the States bordering thereon" having been presented to the consideration of Congress in House bill 5413, Forty-fifth Congress, third session, it is the duty of the Commission to report upon the merits of the system as set forth in the bill. The first feature of the plan consists in opening an outlet, about ten miles below New Orleans, from the river into Lake Borgne. The idea of making an outlet into this lake was suggested by Mr. Charles Ellet, jr., civil engineer, in 1852 (see Ex. Doc. 20, Thirty-second Congress, first session), in an elaborate report to the Secretary of War on the inundation of the Mississippi River.

The proposition was subsequently discussed at considerable length in the report of Humphreys and Abbot, and rejected by them as impracticable. It was again taken up and examined into by the Levee Commission in 1875, and was by it likewise rejected.

In considering the proposed outlet at Lake Borgne, it is necessary to refer to phenomena attending a class of outlets which cannot be considered as *permanent* ones, and which are similar in their characteristics to those which would attend the proposed one at Lake Borgne, for the reason that the river immediately after their occurrence, whether from artificial or natural causes, commences a process of subdelta formation which in the course of a few years effects their complete closure.

On examination of the appended United States Coast Survey map, showing that part of the delta embracing the passes and about forty miles from the main river, several remarkable systems of extinct channels will be found on each side of the three great passes. The vermiculated appearance of these old outlets is particularly noticeable on the west side of the Southeast Pass and on the west side of the Southwest Pass. The process by which the river closed them up and shut them off is clearly illustrated by a similar process now occurring about three miles above the Head of the Passes. At this point on the map referred to will be seen the largest and most recent outlet or mouth of the Mississippi. It occurred during a flood seventeen years ago, and is known as Cubitt's Gap. It was caused by a small canal between the river and the Gulf, used by fishermen in visiting the oyster banks in the vicinity.

The river and the Gulf at this point were then separated by a narrow margin less than one thousand feet wide. The difference in the surface height of the river and the mean level of the Gulf at the time was a little over three feet. The surface slope or fall through the gap was therefore at first at the rate of about fifteen feet per mile. The rapidity of the escaping water with this enormous fall made the crevasse over two thousand feet wide in a few years, with depths of one hundred feet and over in the gap where the river bank had formerly stood.

As soon as the water passed through the gap its velocity was gradually lost, and the immense volume of sediment with which it was charged was thrown down within a fan-shaped area embracing probably twenty or thirty square miles. The earlier maps of the Coast Survey show no islands outside the gap, but the more recent ones show, by the incipient islands and shoals which now surround it, how rapid has been its subdelta formation. These islands are subdividing the single volume of the river water issuing from it into innumerable bayous and little channels, none of them having at this time a greater depth than 7 feet.

Each flood serves to build up these islands higher and extend their area further into the Gulf. And as this island-building process continues out gulfward, these small channels become more distinctly outlined from the depositing action, which goes on most rapidly in the more sluggish water along their shore-lines. Every overflow serves to build up the banks of these channels and to extend them out into the Gulf, but in their prolongation is to be found the cause which finally cuts off and separates them, perhaps forever, from the main river. The difference of level between the river and the Gulf remains the same that it was at the time of the crevasse, but the enormous slope through the gap, at first equal to about 15 feet per mile, and which must have created an exceedingly rapid current during the first few days after the gap was made, now no longer exists. Every addition to the length of the separate channels which are now forming through the subdelta flattens their slope and consequently reduces the current through them. Ultimately these currents will become too sluggish to transport the sediment contained in the water, and it will be dropped at the upper or river ends of these channels, and they will be finally shut off entirely from all connection with the main river, just as those were which are seen on the map on the west side of Southwest and Southeast passes.

Each successive overflow of the river bank will tend to increase the distance between the river and these extinct outlets, and the wound made in the side of the river by Cubitt's Crevasse will then have been completely healed by a natural process.

Twenty-one miles above the Head of the Passes, a gap similar to Cubitt's occurred about forty years ago, called "The Jump." An immense subdelta was formed there in consequence, and upon it there are now several rice plantations and extensive forests, many of the trees being over 12 inches in diameter.

Innumerable bayous permeate this subdelta and lead to the sea, each having at its mouth a miniature bar like those at the mouths of the great passes, none of them having more than 2 feet of depth at low-water.

At the river entrance to The Jump, the depth is but 3 or 4 feet, and in a few years more it will be fully closed by the river deposits.

The same effort which the river is successfully making to close up The Jump and Cubitt's Crevasse (both of which are high and low water outlets), it is making at the celebrated Bonnet Carré Crevasse, which, being through an artificial embankment or levee, only discharges at high-water. The immense deposits which it has carried out and spread over the land near it have served greatly to reduce the volume of water discharged by the crevasse.

Should an outlet be made to connect the river with Lake Borgne, results precisely similar to those which have occurred at Cubitt's Gap and The Jump must be confidently anticipated. Below Cubitt's Gap it is an undisputed fact that the former depth of the river has been largely reduced since the gap occurred. Below The Jump it is not so definitely known what the shoaling has been, as charts of previous soundings are not now available if any exist, but the Light-House Board has placed two buoys a short distance below The Jump, to warn vessels away from the shoals which exist there. It is not possible to make the proposed outlet into Lake Borgne without creating a shoal in the river below it, and it is not possible to keep it permanently open except at great cost in dredging away the subdelta that would be formed by it. Nor could it be kept permanently open without the slope of the river being ulti-

mately increased from the Head of the Passes to the outlet; after which it would raise the flood surface of the river above the outlet.

With reference to that part of the plan set forth in House bill 5413, relating to the Atchafalaya outlet, the commission suggests that, as Major Benyaurd, of the United States Corps of Engineers, in charge of the government works upon this portion of the Mississippi, has now under consideration the question of the permanent improvement of the mouth of the Red River, with the intention, as expressed in his last annual report, of making a special report thereon at the earliest possible moment, it is not deemed advisable that any work at this locality, except what may be required to check the enlargement of the Atchafalaya, should be recommended by this Commission in anticipation of the matured views and opinions of that officer. This can be done in such locality and in such manner as will not interfere with the navigation of the Red and Atchafalaya rivers, and at a cost not exceeding $10,000.

That part of the plan which involves turning the Red River into the Calcasieu, from a point above Alexandria, is entirely impracticable, it having been ascertained by a line of levels run across from Alexandria, under Major Benyaurd's direction, that the bed of the Calcasieu River is 63 feet higher than the water surface of Red River in time of ordinary flood, while its ordinary flood level is 73 feet above that of Red River. The distance between the two rivers, on the line of levels, which is the shortest line that can be run from Alexandria, is 23.86 miles.

If it is proposed to avoid this difficulty by making the connection with the Calcasieu at a point sufficiently near its mouth to secure the requisite descent in the cut, not only would the expense be so enormous as to be practically prohibitory, but there would still remain the danger, unless the dimensions of both the cut and the Lower Calcasieu be made immoderately large, of widespread destruction by floods during every high-river stage through the region traversed by the outlet.

Although other equally novel propositions are set forth for consideration by Congress in House bill No. 5413, as part of this extensive outlet system, which in the language of the bill is designed to effect the "deepening of the channel of the Mississippi River, reducing the mud flow therein, and filling up the swamps and low places by the deposit, and diminishing the volume of water by absorption and evaporation," the Commission deems it unnecessary to report upon them in detail after this exposition of the Lake Borgne and Calcasieu outlets, inasmuch as the latter constitute the chief features of the entire scheme, and the former are, like them, quite impracticable.

Before dismissing this subject, however, it is pertinent to say that the statements which have been published to support this scheme, regarding the effect produced by the Bonnet Carré outlet, in lowering the flood-line above and below it, have been greatly exaggerated.

The Board of Engineers for the improvement of the low-water navigation of the Mississippi River below Cairo, to whom House bill No. 5413 was referred, say in their report of January 28, 1879, with reference to the effect of the proposed outlet:

> The probable immediate effect of this outlet upon the flood-level of the Mississippi will next be considered. The best basis for a safe estimate is the measured effect of the Great Bell crevasse which occurred just above New Orleans on the right bank, in 1858. Its maximum discharge occurred August 1–17, and was 80,000 cubic feet per second, or about 1-12 of the total discharge of the river at that date.
>
> This lowered the water surface 1.5 feet at its site and produced no sensible effect at Baton Rouge, 124 miles above. One fundamental error of the engineering project on which this bill is based lies in overestimating the distance to which the influence of an outlet extends above its site, and it will be well to elaborate this point.

The influence of the Gulf upon the river at high stages is hardly felt above the mouth of Red River. The high-water and the low-water slopes of the water surface above this point are sensibly the same for long distances. Nothing can be done toward modifying the water-level below which will exert any marked effect at any considerable distance above. That this is so was proved by the Red River and Raccourci cut-offs, which shortened the Mississippi 39 miles near the mouth of Red River and lowered the high-water mark there 4.6 feet in the flood of 1851. This beneficial effect diminished rapidly at points higher up the river, and was not felt at all at a distance of 100 miles.

The same principle of hydraulics which is fundamental, and which logically results from the small function of the slope entering all discharge formulæ, is also illustrated by accurate tidal measurements upon the Mississippi. Thus, for spring-tides the oscillations are—

At the Gulf in flood stages of river, 1.7 feet; in low stage of river, 1.7 feet.

At the Forts (36 miles) in flood stages of the river, 0.6 foot; in low stages of river, 1.4 feet.

At Carrollton (120 miles) in flood stages of the river, 0.3 foot; in low stages of river, 1.1 feet.

At Donaldsonville (192 miles) in flood stages of the river, 0.0; but in low stages of river, 0.9 foot.

At Baton Rouge (244 miles) in flood stages of the river, 0.0 foot; in low stages of river, 0.4 foot.

At Red River (315 miles) in flood stages of the river, 0.0 foot; in low stages of river, 0.0 foot.

It is true that the temporary duration of the tidal rise at the river mouth diminishes its effect on the upper river, but nevertheless the facts given for the tides illustrate the general fact that the effect of lowering the river surface at a given point dies out rapidly in ascending.

THE LEVEE SYSTEM.

Levees have never been erected upon the banks of the Mississippi River except for the special purpose of protecting the alluvial lands from overflow. They have, therefore, always had sole reference to the high-water stage, and the degree to which levees might prudently be relied upon "to improve and give safety to navigation," "promote and facilitate commerce, trade, and the postal service," has not hitherto entered into the question of the construction and maintenance of a levee system.

There is no doubt that the levees exert a direct action in deepening the channel and enlarging the bed of the river during those periods of "rise" or "flood" when by preventing the dispersion of the flood-waters over the adjacent low-lands, either over the river banks or through bayous and other openings, they actually cause the water to rise to a higher level within the river-bed than it would attain if not thus restrained.

It would seem to follow, from the law that the volume of water flowing in the bed determines the size, that prior to the construction of levees the area of the mean cross-section of bed of the Mississippi River must have been less than it was after the levees had reached their most efficient condition, assuming, what is believed to be true, that the average rainfall in the Mississippi Valley has not materially changed within the last hundred years.

There is some evidence in a comparison of the results of Young, Poussin, and Tuttle's examination of 1821, with later surveys, that the width of the river has increased since that date.

As silt-bearing streams in alluvial districts have a tendency to assume in the straight reaches cross-sections which are arcs of circles, and in the bends curves of deeper forms, it follows that any general widening of the river resulting from concentration or increase of volume, which may have taken place, would as a rule be accompanied by a general and corresponding deepening as the result of such general enlargement, although local shoalings, temporarily injurious to navigation might occur.

There is reason to believe that during the period when levees were in their most perfect condition, from 1850 to 1858, the channel of the river was better generally for purposes of navigation than it has been since that time.

It is known that during the last twenty years the levee system has been continuously interrupted by a great number of crevasses between Cairo and Red River.

Before the levees were built, a large portion of the flood-waters spread out over the banks of the river in a thin sheet, of which the average depth at the margin of the stream, where it escaped, did not probably exceed a few inches, or, at most, a foot. The immediate effect of the levees would be to increase the volume and height and accelerate the velocity of the flood-waters between them, resulting in an erosion and deepening of the river-bed, and ultimately in a corresponding lowering of the flood-slope, in accordance with the general law already quoted, that an increase in the normal volume of discharge in a sedimentary stream flowing through alluvial deposits, results ultimately in a lowering of the flood surface. It would seem, therefore, that a closure of the crevasses might be expected to accelerate the removal of those shoals which have been produced by them, and if their closure be accompanied by the requisite contraction of the channel to a more nearly uniform high-water width, a lowering of the flood-level may be expected to such extent as will ultimately render the maintenance of the levees as an aid to navigation practically needless above Red River, and greatly lessen the necessity of their permanent maintenance for that purpose below Red River, even at a reduced height.

While it is not claimed that levees in themselves are necessary as a means of securing ultimately a deep channel for navigation, it is believed that the repair and maintenance of the extensive lines already existing will hasten the work of channel improvement through the increased scour and depth of river bed which they would produce during the high-river stages. They are regarded as a desirable, though not a necessary, adjunct in the general system of improvement submitted.

It is obvious that levees are, upon a large portion of the river, essential to prevent destruction to life and property by overflow. They give safety and ease to navigation and promote and facilitate commerce and trade by establishing banks or landing-places above the reach of floods, upon which produce can be placed while awaiting shipment and where steamboats and other river craft can land in times of high-water.

In a restricted sense, as auxiliary to a plan of channel improvement only, the construction and maintenance of a levee system is not demanded. But in a larger sense, as embracing not only beneficial effects upon the channel, but as a protection against destructive floods, a levee system is essential; and such system also promotes and facilitates commerce, trade, and the postal service.

A levee system aids and facilitates the postal service by protecting from injury and destruction by freshets and floods the various common roads and railways upon which that service is conducted to and from the river bank, and generally within that portion of the alluvial region subject to overflow. Moreover the permanent maintenance below Cairo of a connected levee system, a system of sufficient strength to inspire confidence in its efficiency, or the demonstration, by the achieved results of an improved river, that overflow need no longer be seriously apprehended, would act as a prompt and powerful stimulant in rapidly developing a largely increased trade and commerce in all the products of

agricultural industry indigenous to that region, and in those branches of manufacturing enterprise related thereto.

The foregoing is submitted as the opinions of this Commission, with regard to the attributes and functions of levees, and their general utility and value. The views of the several members, however, are not in entire accord with respect to the degree of importance which should attach to the concentration of flood-waters by levees, as a factor in the plan of improvement of low-water navigation, which has received the unanimous preference of the Commission.

The breaks in the levees were estimated in January, 1875, by the commission for the reclamation of the alluvial basin of the Mississippi River, to amount to 8,065,700 cubic yards. It is believed that the repairs done in Louisiana and Mississippi since that time will fully equal the enlargment of the openings in Arkansas and Missouri. The estimate of the cost of closing the breaks in the existing system of levees to the former height is based upon this hypothesis.

The want of completed surveys and the limited supply of labor would render difficult the construction of more than one-half of this amount of work in any one year.

ESTIMATE OF COST.

For closing to their former height the gaps in the existing levees between Cairo and New Orleans, 8,065,700 cubic yards of earthwork, at 23 cents per yard	$1,855,111
Add for contingencies	164,889
Total for repairs of existing levees	2,020,000

This does not include the cost of maintenance, for which no reliable estimate can be made in the absence of data giving the required dimensions of the levees and their positions relative to caving banks. For the absolute prevention of destructive floods, the former height of the levees would have to be increased, but no exact estimate of the cost of these higher levees can be made at present for want of the necessary data.

PLAN OF IMPROVEMENT RECOMMENDED.

The bad navigation of the river is produced by the caving and erosion of its banks, and the excessive widths and the bars and shoals resulting directly therefrom.

It has been observed in the Mississippi River, and is indeed true of all silt-bearing streams flowing through alluvial deposits, that the more nearly the high-river width, or width between the banks approaches to uniformity, the more nearly uniform will be the channel depth, the less will be the variations of velocity, and the less the rate of caving to be expected in concave bends. This would seem to be so in the very nature of things, because uniformity of width secured by contraction will produce increased velocity, and therefore increased erosion of bed at the shoal places, accompanied by a corresponding deposit of silt at the deep places, and consequently greater uniformity of depth.

Uniform depth joined to uniform width, that is to say, uniformity of effective cross-section, implies uniform velocity, and this means that there will be no violent eddies and cross-currents, and no great and sudden fluctuations in the silt-transporting power of the current. There will therefore be less erosion from oblique currents and eddies. and no formations of shoals and bars produced by silt taken up from one part of the channel and dropped in another. As the friction of the bed re-

tards the flow of the water, any diminution of the friction will promote the discharge of floods. The frictional surface is greater in proportion to volume of discharge where the river is wide and shoal than where it is narrow and deep. It follows, therefore, that after the wide shoal places are suitably narrowed, and the normal sectional area is restored by deepening the channel, the friction will be less than it was before. This will result in a more easy and rapid discharge of the flowing water, and consequently in a lowering of the flood-surface. It would seem, therefore, that the plan of improvement must comprise, as its essential features, the contraction of the water-way of the river to a comparatively uniform width, and the protection of caving banks, and this is presumed to be the plan referred to in the act as the "jetty system." It is known, from observation of the river below Cairo, not only that shoals and bars, producing insufficient depth and bad navigation, are always accompanied by a low-water width exceeding 3,000 feet, but that wherever the river does not exceed that width there is a good channel. In other words, bad navigation invariably accompanies a wide low-river water-way, and good navigation a narrow one.

The work to be done, therefore, is to scour out and maintain a channel through the shoals and bars existing in those portions of the river where the width is excessive, and to build up new banks and develop new shore-lines, so as to establish as far as practicable the requisite conditions of uniform velocity for all stages of the river.

It is believed that this improvement can be accomplished below Cairo by contracting the low-water channel way to an approximately uniform width of about 3,000 feet, for the purpose of scouring out a channel through the shoals and bars, and by causing, through the action of appropriate works constructed at suitable localities, the deposition of sand and other earthy materials transported by the water upon the dry bars and other portions of the present bed not embraced within the limits of the proposed low-water channel. The ultimate effect sought to be produced by such deposits is a comparative uniformity in the width of the high-water channel of the river.

It is believed that the works estimated for in this report will create and establish a depth of at least 10 feet at extreme low stages of the river over all the bars below Cairo, where they are located.

It is the opinion of this Commission that, as a general rule, the channel should be fixed and maintained in its present location, and that no attempt should be made to straighten the river or to shorten it by cut-offs.

The borings which were made in 1879 at New Madrid and Plum Point, by direction of the Board of Engineers, for the improvement of the low-water navigation of the Mississippi River below Cairo, and those of more recent date at Memphis and Helena, made under the orders of this Commission, as well as those near Lake Borgne, reported by the levee commission of 1875, and others made along the proposed line of the Fort Saint Philip Canal, and the artesian well sunk at New Orleans, all furnish concurrent evidence of the yielding character of the strata forming the river-bed. This evidence, taken in connection with the fact that deep water is found in all the bends of the river where the width is not excessive, and that these bends have, by their shiftings at one time or another, probably occupied and covered nearly every part of the belt from 10 to 20 miles in width from Cairo to the Gulf, point to the conclusion, if it does not indeed justify it, that there is no extensive stratum of material capable of resisting erosion and preventing the river

from deepening its own bed. In exceptional localities, where the material is too tough or the gravel too heavy for removal by scour, dredging may have to be resorted to as an auxiliary, the depth secured by this means being maintained by the works erected for narrowing the stream.

Experience, as well in this country as in Europe, justifies the belief that the requisite correction and equalization of the transverse profile of the stream, by developing new shore-lines and building up new banks, may be made chiefly through the instrumentalities of light, flexible, and comparatively inexpensive constructions of poles and brush, and materials of like character. These constructions will commonly be open or permeable to such degree that, without too violently arresting the flow of water, thereby unduly increasing the head and causing dangerous underscour, they will sufficiently check the current to induce a deposit of silt in selected localities.

The works which have been used in similar improvements are of various forms and devices, such as the hurdle, composed of a line of stakes or light piles, with brush interlaced; the open dike, formed of stakes with waling strips on both sides filled in loosely with brush; the continuous brush mattress, built or woven on fixed or floating ways and launched as fast as completed, as a revetment to a caving bank, the mattress used as a vertical or inclined curtain, placed in the stream to check the current, the same laid flat on the bottom as the foundation for such a curtain or as an anchorage for other brush devices; curtains of wire or brush netting, placed vertically or inclined in the stream; and various other forms of permeable brush dikes, jetties, or revetments. Some of these methods of construction have been used on the Mississippi and Missouri Rivers with increasing satisfaction and success, although they cannot yet be regarded as entirely beyond the experimental stage. In some, perhaps in many localities, works of a much more solid character than those above indicated may be necessary.

The closure of deep channels or low-water chutes, with a view of confining the flow to a single passage, may require substantial dams of brush and riprap stone or gravel, but it is believed the lighter and less costly works will generally suffice.

By a permeable dike located upon the new shore-line to be developed, connected with the old bank at suitable intervals by cross-lines of like character, or by jetties of hurdles or other permeable works projecting from the bank with their channel ends terminating on the margin to the proposed water-way, or by any other equivalent works, the area to be reclaimed and raised will be converted into a series of silting basins, from which the water, flowing through the barriers with diminished velocity, will, after depositing its heavier material, pass off and give place to a new supply. In this manner the accretion will go on continuously through the high-water season, or through two or more seasons if necessary, the works being renewed on the higher level as occasion requires.

Wherever necessary, the new bank must be protected by a mattress, revetment, or some equivalent device.

That these methods of improvement are practicable, is shown by the works already executed on the Mississippi and Missouri rivers.

The plan submitted by the Board of Engineers for the improvement of the low-water navigation of the river below Cairo, in their report dated January 25, 1879 (see House Ex. Doc. No. 41, Forty-fifth Congress, third session), in which it is recommended that $600,000 be asked for the improvement of the Plum Point Reach, and "that the improve-

ment be effected by narrowing the shoal and wide portions of the low-water river to about 3,500 feet, and by protecting caving banks where necessary," is substantially adopted for the initial works submitted for construction in this report.

An accurate estimate of the cost of properly improving the entire river below Cairo cannot be made until after the completion of the surveys now in progress. Moreover, estimates based upon the latest data from those surveys will doubtless require modification in some particulars, to meet subsequent changes in the river, and will perhaps be considerably reduced in the aggregate amount by improved methods of construction developed during the progress of the work.

INITIAL WORKS.

Under the authority conferred in section 5 of the act, estimates of cost of certain initial works, constituting a component part of the general system of works contemplated, are submitted.

Those works of channel contraction and bank protection, which in the judgment of this Commission may be advantageously undertaken during the coming fiscal year or as soon as Congress supplies the means, are confined to an aggregate length of nearly 200 miles of the shoalest water below Cairo, embracing the following localities, viz: New Madrid, Plum Point, Memphis, Helena, Choctaw Bend, and Lake Providence.

The estimates are intended to cover the cost of works for contracting the channel and for securing and protecting the banks; for the necessary outfit of boats, tugs, tools, &c., to carry on the work for local surveys, the salaries of engineers, superintendents, and inspectors, and the necessary office expenses. Further appropriations will be needed to complete the works, secure their permanence, and develop the full benefit of the system.

As regards the final cost, the novelty of the devices to be employed and the absence of experience with respect to the rapidity and degree of their results, forbid any exact estimate; but it is believed that such additional works as will ultimately be required to complete and render permanent the improvement contemplated in this system at the localities specified will not exceed the amount hereinbelow stated as needed for initial works.

It is considered necessary that a contingent sum, which is inserted in the estimates for initial work, be appropriated for use in any emergency that may arise for securing or protecting the works at any point after the specific appropriation may have been exhausted.

ESTIMATES.

New Madrid Reach, 40 miles long:	
Works for contracting the channel and protecting the banks	$776,000
For outfit, superintendence, inspection, office expenses, and local surveys	147,000
Total for New Madrid Reach	923,000
Plum Point Reach, 38 miles long:	
Works for contracting the channel and protecting the banks	559,000
For outfit, superintendence, inspection, office expenses, and local surveys	137,000
Total for Plum Point Reach	736,000

Memphis Reach, 16 miles long:	
Works for contracting the channel and protecting the banks	$282,000
For outfit, superintendence, inspection, office expenses, and local surveys	100,000
Total for Memphis Reach	382,000
Helena Reach, 30 miles long:	
Works for contracting the channel and protecting the banks	515,000
For outfit, superintendence, inspection, office expenses, and local surveys	112,000
Total for Helena Reach	627,000
Choctaw Bend, 35 miles long:	
Works for contracting the channel and protecting the banks	464,000
For outfit, superintendence, inspection, office expenses, and surveys	112,000
Total for Choctaw Bend	576,000
Lake Providence Reach, 25 miles long:	
Works for contracting the channel and protecting the banks	507,000
For outfit, superintendence, inspection, office expenses, and local surveys	112,000
Total for Providence Reach	619,000
Contingencies	250,000

Should it be determined not to appropriate the amounts estimated for all the initial works, it is considered important that the reduction should be made rather in the number of places at which work is proposed than by reducing the estimates for any one place.

ESTIMATES FOR WORKS OF IMPROVEMENT FOR THE FIRST FISCAL YEAR.

Initial works for channel contraction and bank protection	$4,113,000
Closing gaps in levees	1,010,000
Checking enlargement of Atchafalaya	10,000

ESTIMATES FOR SURVEYS AND FOR EXPENSES OF COMMISSION FOR FISCAL YEAR ENDING JUNE 30, 1881.

For surveys and examinations above and below Cairo, and the necessary salaries and other expenses of the Mississippi River Commission	$200,000

If Congress shall authorize any extensive works of improvement on the Mississippi, we would respectfully suggest that provision be made by law for the appropriation of such land and materials as may be needed in the work when the same cannot be obtained upon equitable terms by purchase from the owner. We do not contemplate that a resort to such proceedings would often be necessary, but in the absence of any such provision of law individual owners of the property required might greatly and unjustly enhance the cost of the work.

Authority to file in the proper court of the United States an article of appropriation describing the property to be taken, and to have an assessment by competent appraisers of its value, would tend to prevent extortion, and at the same time secure to the individual a just recompense for the property taken.

We venture to suggest further that, in case the Commission should be continued in existence and the works recommended by it be in whole or in part authorized by Congress, the execution of the work and the expenditure of the appropriations therefor shall not be made part of the duty of the Commission. We think the duties of the Commission should be limited to the preparation of plans, their modification when neces-

sary, the advisory supervision of the work, and the completion of the surveys and observations. This would secure unity of plan, greater efficiency in the work, and a better system of checks upon the expenditures than we could hope to secure if the entire work of devising, executing, and disbursing were cast upon the Commission.

All of which is respectfully submitted.

Q. A. GILLMORE,
Lieutenant-Colonel of Engineers, Bvt. Maj. Gen.,
President Mississippi River Commission.
CHAS. R. SUTER,
Major of Engineers, U. S. A.
HENRY MITCHELL,
Coast and Geodetic Survey.
JAS. B. EADS.
B. M. HARROD.

Hon. ALEXANDER RAMSEY,
Secretary of War, Washington, D. C.

APPENDIX 1.

FINANCIAL STATEMENT.

WASHINGTON, D. C., *February* 16, 1880.

Amount appropriated for expenses of the Mississippi River Commission, by act approved June 28, 1879		$175,000 00
Amount expended to February 16, 1880, including outstanding liabilities:		
For surveys and observations	$65,691 21	
For salaries of Commissioners	5,024 99	
For mileage and inspection	8,167 88	
For reduction of maps	1,920 70	
For office expenses	4,195 22	
Balance which is estimated will be required during remainder of the fiscal year ending June 30, 1880	90,000 00	
		175,000 00

SMITH S. LEACH,
First Lieutenant of Engineers, U. S. A.,
Secretary Mississippi River Commission.

THE MISSISSIPPI RIVER COMMISSION,
PRESIDENT'S OFFICE, ARMY BUILDING,
33 WEST HOUSTON STREET,
New York, March 8, 1880.

SIR: I have the honor to transmit herewith the minority report of General Comstock and Mr. Harrison, to be attached to the report of the Mississippi River Commission forwarded with my letter of the 6th instant.

Very respectfully, your obedient servant,

Q. A. GILLMORE,
Lieutenant-Colonel of Engineers, Bvt. Maj. Gen., U. S. A.,
President Mississippi River Commission.

Hon. ALEXANDER RAMSEY,
Secretary of War, Washington, D. C.

[Indorsement.]

OFFICE CHIEF OF ENGINEERS, U. S. ARMY,
March 9, 1880.

Respectfully forwarded to the honorable the Secretary of War, to accompany report of Mississippi River Commission transmitted on the 8th instant.

H. G. WRIGHT,
Chief of Engineers,
Brig. and Bvt. Maj. Gen.

MINORITY REPORT.

While of the opinion that an ample depth of water for navigation on the Mississippi River below Cairo can be obtained by contraction of the low-water width at shoal places to about 3,000 feet, erosion being aided by dredging if necessary; and while of the opinion that levees are essential to prevent injury to alluvial lands by destructive floods, and that outlets should not in general be used, there are some less important points on which we do not concur in the views of the majority of the Commission.

1. We cannot concur in the unqualified form of expression of certain theoretical views, believing them to have too many exceptions to furnish safe bases for practical conclusions. One such statement is:

> If the normal volume of water in a silt-bearing stream, flowing in an alluvial bed of its own formation, be permanently increased, there will result * * * ultimately a lowering of the surface slope.

While this statement and its converse are usually true, they yet omit some factors which influence the relation between discharge and slope. One is the coarseness and quantity of the sediment which the increase of volume brings; another is the ratio of flood to low-water discharge; and another the varying coarseness of the material forming the bed of the river at the same place at different times or at different places.

When the increase of volume brings with it much coarse sediment, the slope may be increased instead of diminished, by increase of volume. This effect has been frequently observed below the mouths of tributaries.

Again, if the ratio of flood to low-water discharge could be made to approach unity, the annual discharge remaining unchanged, it is probable that the Middle Mississippi would have a smaller slope than at present, approaching that of the river below New Orleans, where the flood rise is small. In that case the annual discharge might be diminished without increasing the slope beyond its present value.

2. We do not concur with the majority of the Commission in their estimate of the value of the closure of gaps in existing levees as a factor in the improvement of low-water navigation; this estimate being derived in part from the theoretical views already referred to.

Existing evidence seems to show that during low-water stages the bars below Cairo are usually cut out by the river, and that when the period of low river in the following season approaches, these low-water channels are found filled up, the low-water bed of the river in these shoal places having risen, to be again cut out by the low river. (See Major Suter's report in Report of Chief of Engineers, 1875.)

At the Horse Tail Bar, below Saint Louis, the bed of the river has been observed to rise 8 or 10 feet above low-water in the interval be-

tween two low-river periods. (See General Simpson's report in Chief of Engineers' report, 1876.)

If, then, the final effect of a flood which rises from 30 to 50 feet above low-water is to raise the low-water bed of the river at shoal places, may it not be possible that if the height of this flood be somewhat increased by levees the bed may rise still further instead of being depressed, thus injuring instead of improving navigation.

But even if a rise or fall of a foot or two in the bed of the river were produced by levees, it is difficult to see how this would sensibly affect the low-water width of the river. Bad navigation arises from excessive low-water width at certain places, and is to be cured by contracting that low-water width to about 3,000 feet. This contraction must be effected by works in the bed of the river, and not by levees on top of its banks, out of contact with the low-water river.

For these reasons we are of the opinion that levees are of very little value in improving the low-water navigation of the river. Of their necessity in protecting alluvial lands against destructive floods there can be no doubt, and to obtain such protection the first step would be the closure of gaps in existing levees. The regulation of the low-water river, including the fixation of the river banks, would be of the greatest aid to the levees, since it would secure them from destruction by caving.

The majority report anticipates as a result of the proposed works a lowering of the flood-level to such an extent "as will ultimately render the maintenance of the levees as an aid to navigation practically needless above Red River."

As to the larger question, whether the proposed works will make levees unnecessary to prevent destructive floods on this part of the river, there are, in our opinion, no sufficient data for drawing reliable conclusions; theoretically they should in some degree lower the bed.

A reduction of the flood-level is very desirable, but where on other rivers this has been effected, cut-offs have usually played an essential part. For this reason we are not prepared to absolutely reject their use, after the banks of the river have been thoroughly protected for considerable distances above and below the sites where they are about to occur.

3. From the lack of sufficient experience, either in this country or abroad, in the improvement of rivers by the means recommended in the report, the estimates of cost can only be considered as rough approximations, since the strength needed for the work will have to be determined by trial. For this reason we think it in the interest of economy that works should not in the first year be undertaken at more than one or two of the points for which estimates are submitted.

C. B. COMSTOCK,
Major of Engineers and Bvt. Brig. Gen.
BENJAMIN HARRISON.

REPORT.*

OFFICE OF MISSISSIPPI RIVER COMMISSION,
Saint Louis, January 8, 1881.

SIR: The Mississippi River Commission has the honor to submit the following report, embracing—

1. A statement of the progress made in surveys, observations, and examinations.

*H. R. Ex. Doc. 95, 46th Cong., 2d sess.