REPORT

ON THE

OVERFLOWS OF THE DELTA

OF

THE MISSISSIPPI:

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Introduction.

In this report, the causes of the more frequent and more extensive overflows of the delta of the Mississippi, in recent than in former times, are considered, and plans suggested for the mitigation of the evil.

The greater frequency and more alarming character of the floods are attributed—

Primarily, to the extension of cultivation, throughout the Mississippi valley, by which the evaporation is thought to be, in the aggregate, diminished, the drainage obviously increased, and the floods hurried forward more rapidly into the country below.

Secondly, to the extension of the levees along the borders of the Mississippi, and of its tributaries and outlets, by means of which the water that was formerly allowed to spread over many thousand square miles of low lands, is becoming more and more confined to the immediate channel of the river, and is, therefore, compelled to rise higher and flow faster, until, under the increased power of the current, it may have time to excavate a wider and deeper trench to give vent to the increased volume which it conveys.

Thirdly, to *cut-offs*, natural and artificial, by which the distance traversed by the stream is shortened, its slope and velocity increased, and the water consequently brought down more rapidly from the country above, and precipitated more rapidly upon the country below.

Fourthly, to the gradual progress of the delta into the sea, by which the course of the river, at its embouchure, is lengthened, the slope and velocity there are diminished, and the water consequently thrown back upon the lands above.

It is shown that each of these causes is likely to be progressive, and that the future floods throughout the length and breadth of the delta, and along the great streams tributary to the Mississippi, are destined to rise higher and higher, as society spreads over the upper States, as population adjacent to the river increases, and the inundated low lands appreciate in value.

For the prevention of the increasing dangers growing out of these several co-operative causes, six distinct plans are discussed and advocated :

First—Better, higher and stronger levees in Lower Louisiana, and more efficient surveillance—a local measure, but one requiring State legislation, and official execution and discipline.

Second—The prevention of additional cut-offs ; a restraint which may call for national legislation, or possibly judicial interference, to prohibit the States and individuals above from deluging the country below.

Third—The formation of an outlet of the greatest attainable capacity,

from the Mississippi to the head of Lake Borgne, with a view, if possible, to convert it ultimately into the main channel of the river.

Fourthly—The enlargement of the Bayou Plaquemine, for the purpose of giving prompt relief to that part of the coast which now suffers most from the floods, viz: to the borders of the Mississippi from above Baton Rouge to New Orleans.

Fifth—The enlargement of the channel of the Atchafalaya, for the purpose of extending relief higher up the coast, and conveying to the sea, by an independent passage, the discharge from Red river and the Washita.

Sixth—The creation of great artificial reservoirs, and the increase of the capacity of the lakes on the distant tributaries, by placing dams across their outlets with apertures sufficient for their uniform discharge—so as to retain a portion of the water above until the floods have subsided below. It is proposed by this process to compensate, in some degree, for the loss of those natural reservoirs which have been and are yet to be destroyed by the levees: and at the same time, and by the same expedient, improve the navigation of all the great tributaries of the Mississippi, while affording relief to the suffering and injured population of the delta.

It will be seen that these several plans harmonize with each other, and may be carried on simultaneously.

It will be shown, moreover, that they will all be needed, and that they must be adopted promptly and prosecuted vigorously, to afford efficient and timely protection: and that, if adopted, and pressed forward boldly, they will ultimately secure the immediate object of Congress—the protection of the coasts of the Mississippi from overflow, and simultaneously the perfection of twenty thousand miles of precarious navigation, and the ultimate drainage and cultivation of fifteen or twenty millions of acres of unhabitable swamps.

Nothing will more forcibly impress the mind of the practical man with the inestimable value of the Mississippi and its tributaries, as a social, commercial, and political bond of this happy country, than the comprehensive study of the grand and beautiful problem of controlling their waters.

The writer is fully aware of the distrust with which some of his views on this subject have been, and may yet be for a season, regarded. But he submits his plans to the calm consideration of an enlightened public, in the confident belief that every year, and each succeeding flood, will secure for them closer attention and additional strength.

Report on the means of protecting the Delta of the Mississippi from inundations.

PART I.

OF THE PHYSICAL CHARACTERISTICS OF THE DELTA OF THE MISSISSIPPI.

The delta of the Mississippi is usually assumed to extend from the Gulf of Mexico to the point at which rock *in situ* is first encountered on both sides of its channel, and supposed to be found in the bed. This point is near the village of Commerce, about twenty-eight miles above the mouth of the Ohio. But if we mean to designate by THE DELTA that formation of alluvial soil through which the Mississippi now flows, and which has

been raised above the sea by the earthy matter brought by the river from the highlands, it will be difficult to assign its true northern limit. There is no evidence that the Gulf of Mexico, in the present order of things, and under the present adjustment of land and water, ever washed the base of the hills north of the Ohio.

If that fact be assumed, it involves the further assumption that there existed at some remote period a cataract or rapids, having a descent greater than the pitch of Niagara, somewhere above the mouth of the Ohio. The elevation of the low water surface of the Mississippi between Commerce and Cape Girardeau is two hundred and eighty-five feet above the level of the ocean; and if the present level of the sea ever extended up to that point, the Mississippi must then and there have precipitated its waters over a ledge two hundred and eighty-five feet high.

Without intending to maintain this assumption, which has never been supported by facts or demonstration, for the present purposes we may adopt the mouth of the Ohio as the head of the delta, though only for the convenience of assigning some limit to the field of investigation.

To be able to form a just conception of the present physical constitution of the delta, and the causes of its overflow, we must imagine a great plane sloping uniformly from the mouth of the Ohio, in a direction deviating but little from a due southerly course, to the Gulf of Mexico. The length of this plane, from the mouth of the river to the waters of the gulf, is five hundred miles. Its northern extremity is elevated two hundred and seventy-five feet above the surface of the sea, and is there and everywhere nearly level with low water in the Mississippi river. Its total descent, following the highest surface of the soil, is about three hundred and twenty feet, or at the rate of eight inches per mile.

The breadth of this plane near the mouth of the Ohio, in an east and west direction, is from thirty to forty miles, and at the Gulf of Mexico it spreads out to a width of about one hundred and fifty miles. It is enclosed on the east and west by a line of bluffs of irregular height and extremely irregular direction.

This plane, containing about 40,000 square miles, has been formed in the course of ages from the material brought down from the uplands by the Mississippi and its tributaries. The river has therefore raised from the sea the soil which constitutes its own bed. It flows down this plane of its own creation, in a serpentine course, frequently crowding on the hills to the left, and once passing to the opposite side and washing the base of the bluff which makes its appearance on the west at Helena.

The actual distance from the mouth of the Ohio to the coast of the gulf is, as stated, in round numbers, five hundred miles. The computed length of the Mississippi river from its confluence with the Ohio to the mouth of the Southwest Pass is 1,178 miles, and the average descent at high water $\frac{27}{1665}$ of a foot, or $3\frac{1}{4}$ inches per mile.

The course of the river is therefore lengthened out nearly seven hundred miles, or is more than doubled by the remarkable flexures of its channel; and the rate of its descent is reduced by these flexures to less than one-half that of the plane down which it flows.

In the summer and autumn, when the river is low and water is scantily supplied by its tributaries, the surface of the Mississippi is depressed at the head of the delta about forty feet, and as we approach New Orleans, twenty feet below the top of its banks. It then flows along sluggishly in

a trench about 3,000 feet wide, 75 feet deep at the head, and 120 feet at the foot, and enclosed by alluvial and often caving banks, which rise, as stated, from twenty to forty feet above the water.

But when the autumnal rains set in, the river usually rises until the month of May, when it fills up its channel, overflows its banks and spreads many miles over the low lands to the right and left of its trace. This leads to another important feature in the characteristics of this stream.

The Mississippi bears along at all times, but especially in the periods of flood, a vast amount of earthy matter suspended in its waters, which the current is able to carry forward so long as the river is confined to its channel. But when the water overflows its banks, its velocity is checked, and it immediately deposites the heaviest particles which it transports, and leaves them upon its borders: and as the water continues to spread further from the banks, it continues to let down more and more of this suspended material, the heaviest particles being deposited on the banks, and the finest clay being conveyed to positions most remote from the banks.

The consequence is, that the borders of the river which received the first and heaviest deposite are raised higher above the general level of the plane than the soil which is more remote; and that, while the plane of the delta dips towards the sea at the rate of eight inches per mile, the soil adjacent to the banks slopes off at right-angles to the course of the river into the interior, for five or six miles, at the rate of three or four feet per mile.

These lateral slopes, with the high water and low water levels of the Mississippi and the artificial levees, are exhibited in the annexed section, (fig. 1,) which is a fair average obtained from a number of surveys made at various points between Donaldsonville and Baton Rouge, by Messrs. H and William G. Waller, civil engineers.

It will be perceived from this section and description, that in times of flood, the surface of the Mississippi is eighteen or twenty feet higher than the level of a great part of the actual delta; and that, at low water, its surface is found in the very lowest depression of the delta; so that all the lateral streams and adjacent low grounds have then a natural drainage towards its channel.

The lands immediately on the borders of the river are extremely fertile, and often highly cultivated. But as they are all subject to inundations by the high floods of the river, they are guarded by artificial embankments, which have been thrown up in front of each plantation by the individual proprietors. The water presses upon these embankments, and often produces breaches through them; when, as may be readily appreciated from the representation above, it rushes in a deep column into the low grounds, from which it had been previously excluded by the levees, and sweeps over any improvements that may have obtained a foot-hold there. It is to find means to prevent the disasters incident to these crevasses, and to prevent the overflow of these low grounds, or swamp lands generally—covering, it is supposed, nearly 40,000 square miles—that the reconnoissance, of which the results are now given, has been instituted.

What is here said of the Mississippi applies equally, though with modifications due to the difference in the magnitude of the streams, to all the tributaries, great and small, which flow into it, from the mouth of the Ohio to the sea. Each tributary is enclosed, at low water, by banks twenty or thirty feet high, which it overflows at periods of flood, mingling its waters of overflow in the lateral low grounds with those of the Mississippi. The

immediate borders of each tributary likewise exhibit deposites, made by the tributary, highest at the edge of the channel, and sloping off laterally to the adjacent lowlands, presenting a narrow strip of cultivated or arable soil, near the winding channel, and great unbroken swamps beyond.

The delta of the Mississippi was, therefore, in its natural condition, at high water, a vast inundated tract, through the lowest depression of which might be traced the channel of the river, absorbing numerous tributaries in its course, each of which found its way to the common recipient along the most depressed portions of the adjacent lowlands.

In times of great floods, there was then but an inconsiderable area of land elevated above the water; but as the river fell, the course of its channel might be defined by two narrow strips of soil, rising in parallel belts above the surface; from which, as the water continued to recede, there would become gradually visible the parallel borders of the tributaries, and their countless bayous, forming a double net-work of natural embankments, with rivers of various dimensions enclosed between them, over the whole area of the delta.

It is in the highest degree important that this description should be made clear; for it will presently be shown that it is essentially the exclusion of this water of overflow from the swamps, that is now creating so much distress in lower Louisiana; while to remove the water and reclaim these swamps, has become a prominent object of national and State legislation.

The subject is of vast interest, highly complicated and full of difficulty. But the lands which are now annually overflowed, may certainly be estimated at fully 16,000,000 of acres, which, if relieved by any effectual process, would be worth, at the government price, $20,000,000; but converted, as they may be, into sugar and cotton fields, would possess a value that it might seem extravagant to state; while the annual loss and distress of the present population caused by the inundations of the river can scarcely find a parallel, excepting in the effects of national hostilities.

WIDTH OF THE MISSISSIPPI.

The Mississippi is usually described as remarkable for the uniformity of its surface width. And if we take great sections, and compare the average breadth in consecutive reaches extending from one great tributary to another, we shall certainly be struck with the uniformity of these averages, and the very small impression produced upon the apparent magnitude of the stream by the immense volumes of water poured into it by its greatest arms. This fact has, indeed, an important bearing upon the subject of overflows; for we shall find that, notwithstanding the vast contributions received from the Ohio, the Arkansas, White, St. Francis, Red and other rivers, the Mississippi, in flood, actually conveys less water into the Gulf of Mexico in a unit of time, *through its channel*, than it carries past Cape Girardeau, or other points, twelve hundred miles above its mouth.

But notwithstanding this general truth, this great river presents as frequent and as sudden changes of width, depth and velocity, as are exhibited by other streams. Let us take, for example, three measurements of the width of the entire river between banks, in the neighborhood of St. Louis.

Width of the Mississippi river at St. Louis.

Width opposite Market street, (taken at low water in 1839, by Charles Ellet, jr.) - - - - 3,444 feet.
Width above Bloody island, (taken in 1837, by Captain R. E. Lee) - - - - - - 1,314 "
Width at Narrows, three miles above St. Louis, (taken in 1837, by Captain R. E. Lee) - - - 1,835 ".

These measurements show variations in the width at the surface, of nearly one hundred and forty per cent. in the space of three miles; yet the average width at or near St. Louis does not differ materially from the average at Vicksburg or at Donaldsonville. In fact, it will be seen, in comparing the following widths at surface, measured at various points, from Cape Girardeau to the mouth of the river, that there is no general increase of the breadth of the Mississippi, in passing from what is supposed to be its ancient channel to that alluvial bed which it has raised for itself from the sea.

TABLE 1.

Of the width of the Mississippi between banks.

Points.	Feet.
Cape Girardeau, about 1½ mile above,	2,500
Above mouth of Ohio, about 2 miles,	1,530
Below mouth of Ohio, about 1 mile,	4,031
Below Memphis, half a mile,	2,830
At the Horse-Shoe cut-off,	2,940
Above mouth of Arkansas river, three quarters of a mile,	2,810
Below mouth of Arkansas river, three quarters of a mile,	3,730
At American bend, upper side, below Columbia,	3,365
At American bend, lower side,	3,285
Terrapin Neck, Fig. 3, letter P,	3,440
Terrapin Neck, lower side, at letter P',	3,540
Above Vicksburg, about 7 miles,	3,513
Above Vicksburg landing, half a mile,	2,243
Below Vicksburg, about 3 miles,	4,400
Above Palmyra Island bend,	4,048
Below Palmyra Island bend,	5,613
Above Grand Gulf, about 4 miles,	3,644
Below Grand Gulf, about 3 miles,	5,900
Above the mouth of Red river, about half a mile,	2,545
Below the mouth of Red river, about 1 mile,	3,655
Raccourci cut-off, (river still becoming wider here,)	1,761
Tunica bend,	3,323
Baton Rouge, (from the report of Senate committee of Louisiana,)	2,500
Above Plaquemine, one and a half mile,	2,170
Below Plaquemine, one and a half mile,	2,790
Above Donaldsonville, about 1 mile,	2,483
Below Donaldsonville, about half a mile,	3,553
Bonnet Carré bend, above crevasse,	2,925
Bonnet Carré bend, below crevasse,	2,983
Sauvé's plantation, above crevasse,	2,375
At McMaster's plantation, about 11 miles below New Orleans,	2,425
Average width of the Mississippi,	3,236

From these measurements—for which the points of observation were not particularly selected, but taken with a view to obtain other information incident to this investigation—the width of the Mississippi may be said to vary, in the course of the river through the delta, from 2,200 to 5,000 feet, though there are occasionally encountered places where these limits are materially exceeded. In the succeeding investigations, when it may become necessary to use a mean expression for the value of the width, 3,300 feet will be assumed for that average.

There is one fact having a most important practical bearing, which it will be expedient to notice here, as resulting from these measurements. The width of the Mississippi, in the Raccourci cut-off, is, at this time, but 1,761 feet, or only half the measured width at points a few miles above and below the cut-off. This passage has now been open more than three years, yet the power of the whole river rushing through it has not been found sufficient to cut out that narrow neck much beyond the half of the average width of the stream. As the pass becomes enlarged from year to year, the force of the river through it will be correspondingly diminished, and centuries may therefore roll by before that part of the Mississippi is opened as wide as the average dimensions of the channel.

This fact will be again adverted to when we come to consider the merits of that theory which treats with indifference the constantly increasing volume poured down by the river; confiding in the hope that the abrasive power of the current will increase as the volume of water discharged increases, and that this increasing power will always secure an adequate passage for the surplus water. The writer may, therefore, assert now, as he will be forced to maintain hereafter, that this is a delusive hope, and most dangerous to indulge, because it encourages a false security.

OF THE DEPTH OF THE MISSISSIPPI.

The depth of the Mississippi, from above the entrance of the Missouri to a point below the mouth of the Arkansas, exhibits a decided increase with each additional tributary it receives. But below the Arkansas, and especially below the mouth of the Yazoo, though the extreme depths, in mid-channel, may vary materially,—sometimes diminishing down to less than ninety feet and sometimes rising to more than one hundred and eighty feet,—they exhibit no general or progressive increase.

The following table shows the maximum depths found at high water in sounding across from shore to shore at the several points for which the foregoing widths are given:

TABLE II.

Of the extreme depths of the Mississippi at high water of 1850

Points.	Feet.
Cape Girardeau, about 1½ mile above,	66.5
Cape Girardeau, (to high water of 1844.)	76.5
Above mouth of Ohio, about 2 miles,	77.5
Below mouth of Ohio, about 1 mile,	71.3
Below Memphis, half a mile,	102.5
At the Horse-Shoe cut-off,	72.8
Above mouth of Arkansas river, three-fourths of a mile,	81.5
Below mouth of Arkansas river, three-fourths of a mile,	81.0
At American bend, upper side,	103.6
At American bend, lower side,	79.1
Terrapin Neck, Fig. 3, letter P,	87.6
Terrapin Neck, lower side, at letter P',	102.1
Above Vicksburg, about 7 miles,	120.0
Above Vicksburg landing, half a mile,	120.5
Below Vicksburg, about 3 miles,	84.0
Above Palmyra Island bend,	96.3
Below Palmyra Island bend,	91.3
Above Grand Gulf, about 4 miles,	105.5
Below Grand Gulf, about 3 miles,	76.5
Above the mouth of Red river, abour half a mile,	118.0
Below the mouth of Red river, about 1 mile,	128.0
In Raccourci cut-off,	107.0
Tunica bend,	87.7
Above Plaquemine, one and a half mile,	123.5
Below Plaquemine, one and a half mile,	128.0
Above Donaldsonville, about 1 mile,	117.5
Below Donaldsonville, about half a mile,	103.2
Bonnet Carré bend, above the crevasse,	107.9
Bonnet Carré bend, below the crevasse,	76.4
Sauvé's plantation, above the crevasse,	135.3
At McMaster's plantation, about 11 miles below New Orleans,	100.0

From Vicksburg down to New Orleans, we may fairly assume the average depth, in mid-channel way, at high water, to be one hundred and fifteen feet, though there are many points where the depth exceeds one hundred and eighty feet, and others where the extreme does not exceed seventy feet. It is liable also to frequent variations in the same points; light deposites being left on the bottom when the river is low, and swept out again when its force is increased by the flood. The greatest depth found in the course of this investigation was under the bluffs at Grand Gulf, where the lead once reached two hundred feet. A depth of one hundred and eighty-four feet was obtained above Donaldsonville, and one hundred and eighty feet in several other places.

It is worthy of note that the maximum depth of the section taken in the Raccourci cut-off, as well as the width of surface, after having been three years exposed to the action of the river—here greatly increased in power by the contraction of the water-way—is still decidedly below the average.

TABLE III.

Of the section of the Mississippi between banks, in the high water of 1850.

Points.	Sq. feet.
At Cape Girardeau, about 1½ mile above,	105,544
At Cape Girardeau, about 1½ mile above, (flood of 1844,)	130,624
Below mouth of the Ohio, about 1 mile,	235,333
Below Memphis, half a mile,	143,212
At the Horse-Shoe cut-off,	161,221
Above mouth of the Arkansas river, three-fourths of a mile,	171,190
Below mouth of the Arkansas river, three-fourths of a mile,	196,890
At American bend, upper side,	170,160
At American bend, lower side,	187,170
Terrapin Neck, upper side,	178,220
Terrapin Neck, lower side,	168,139
Above Vicksburg, about 7 miles,	160,164
Above Vicksburg landing, half a mile,	177,200
Below Vicksburg, about 3 miles,	207,800
Above Palmyra Island bend,	187,220
Below Palmyra Island bend,	256,292
Above Grand Gulf, about 4 miles,	175,773
Below Grand Gulf, about 3 miles,	264,797
Above the mouth of Red river, about half a mile,	194,530
Below the mouth of Red river, about 1 mile,	268,646
Raccourci cut-off,	148,790
Tunica bend,	233,892
Baton Rouge, (from the report of engineers of Senate committee,)	212,500
Above Plaquemine, one and a half mile,	181,500
Below Plaquemine, one and a half mile,	199,280
Above Donaldsonville, about 1 mile,	200,250
Below Donaldsonville, about half a mile,	214,580
Bonnet Carré bend, above crevasse, (high water of 1849,)	198,734
Bonnet Carré bend, below crevasse, (high water of 1849,)	152,443
Sauvé's plantation, above crevasse, (high water of 1849,)	182,031
At McMaster's plantation, about 11 miles below New Orleans,	166,172
The average area of the high water section of the Mississippi, from Vicksburg to Donaldsonville, inclusive, is	215,200
The average of the whole, from the mouth of the Ohio to New Orleans, is	200,000

It will be again observed, on inspecting this table, that the area of the section of the Mississippi in high water, through the Raccourci cut-off, is but little more than two-thirds of the average area from Vicksburg to Bonnet Carré. The average velocity of the current through that contracted pass, is, therefore, at least forty per cent. greater than the average velocity in other parts of the river below the mouth of the Arkansas. Yet, notwithstanding the fact that the water is so crowded in this gorge, and that its velocity is so much accelerated by the contraction of the channel, it makes exceedingly slow progress in opening the way and regaining its average normal dimensions.

The conclusions which will be drawn from this fact will be found of the highest importance in treating of the effect of cultivation, of cut-offs, and the extension of the levees—in fact in all measures tending to throw more water into any part of the channel in a given time. It will be seen that we must seek to determine the effect of every such increase of supply, without venturing to make allowances for any hypothetical augmentation of the

water-way to be ultimately gained by the increase of the abrasive power of the current.

OF THE VELOCITY OF THE MISSISSIPPI.

Numerous observations were made in the course of these investigations, for the purpose of determining the velocity of the Mississippi. The result of these measurements shows an average surface velocity in the centre of the river, at high water, of about seven feet per second, or nearly five miles per hour; and occasionly places where the speed at the surface is ten or eleven feet per second, or fully seven miles per hour.

But for the purpose of computing the discharge of the river, it is necessary to be able to deduce approximately the velocity of all the currents beneath the surface, or the mean velocity, from observations made at the surface. This problem has occupied the attention of several eminent writers, among whom stand conspicuously the names of Du Buat and De Prony. The formulas published by these writers, respectively, have received the sanction of practical men, and are now almost universally adopted. Yet the experiments made during this inquiry have exhibited results which do not sustain the received rules, when applied to deep and rapid rivers, and which, in fact, are in some respects at variance with all the popular theories.

A primary object of the writer was to ascertain what deduction ought to be made from the observed velocities at the surface of the Mississippi, in order to represent fairly the mean velocity of the whole mass of the river.

For this purpose, lines of different lengths were prepared and so loaded that the lower end would sink while the upper end, and the load at the lower, would be supported by a float on the surface. A line thus prepared was thrown into the river where the depth had been previously ascertained, and when straightened out by the weight below, a surface float was placed alongside of the one which supported the line, and allowed to start from a drifting boat, with the same velocity. These floats were kept together until they were carefully timed as they passed the range previously established on the shores. They were then successively timed again as they passed a second parallel range, established five hundred feet lower down the river. It results from numerous trials, made in this manner, in different parts of the river, in depths varying from fifty-four feet to one hundred feet, and in currents varying from three miles to seven miles per hour, that *the speed of the float supporting a line fifty feet long is almost always greater than that of the surface float.* The average increase of velocity over the surface velocity with a line of fifty feet, obtained from nineteen observations, is *two per cent.*

Four observations in nineteen trials with the fifty-feet line, exhibited under-velocities less than the surface velocities. With a line twenty-five feet long the results were nearly the same in five observations; four of the results with the line being greater than the speed of the surface float. A line seventy-five feet long in ninety-three feet water showed a velocity a little over two per cent. greater than that of the surface float.

A line seventy-five feet long where the depth was eighty-two feet, showed a velocity 2.6 per cent. *less* than that obtained at the surface. But experiments made on the speed so near the bottom must always be received with distrust, as the lower end of the line is liable to come in contact with the soil, or other fixed obstructions. (See note A.)

So far as these experiments go, they lead to the conclusion that the mean

velocity of the Mississippi, instead of being less, is in fact about two per cent. greater than the mean surface velocity. But it has not been deemed proper to make any additions to the volumes deduced from observations on the speed at the surface, in computing the total discharge of the river. It is the opinion of the writer, founded on these experiments and legitimate deductions from them, that the velocity of the water near the surface is retarded by its contact with the atmosphere. As we descend below the surface the effect of this retardation disappears, and at some point about midway between the surface and the bottom the velocity would be a maximum. But at the bottom, a further retardation of course has place, which the time of the writer and the means at his disposal, did not permit him to study. But as such a retardation must occur, it has been deemed proper to assume that it will diminish, if it do not altogether neutralize, the increase of two per cent. observed in the velocities, with a fifty-feet line, over those obtained at the surface.

It is probable that the mean velocity of the Mississippi is a very small fraction greater than the mean velocity of its surface: but as the excess must be very small, certainly less than two per cent., it has been thought proper to compute the discharge in all cases from the surface velocity only.

In deducing the average increase of velocity beneath the surface, no account has been taken of those observations which show remarkable undercurrents produced by eddies and local irregularities. On one occasion, in testing the velocity a few hundred feet from the shore, where the soundings showed a depth of thirty-nine feet, the velocity of a twenty-five feet line was found to be $20\frac{1}{3}$ per cent. greater than that of the surface float; and the speed of a buoy bearing a thirty-five feet line—sweeping within four or five feet of the bottom—was seventeen per cent. greater than that of the surface.

These under-currents are very frequent below the salient angles of the shores, where eddies occur, and great disturbance of the water is produced. But the foregoing results are obtained from observations made in straight channels where no such disturbing causes were observable.

A study of these observations will enable us, moreover, to account for an anomaly sometimes noticed in testing the surface velocities at different distances from the shore in the same part of the river. It occasionally happens that the speed at the surface diminishes as the depth of the sounding increases; contrary to the received hypothesis which assumes that, *cæteris paribus*, the velocity of the surface current increases in some proportion with the depth of the channel. Still, these anomalous results are, in this case, only in appearance in conflict with the popular law. The depth of the river is due, not to the surface velocity, but to the velocity of the water which is in contact with the bottom, and which produces the depth. The deeper soundings found where the surface velocities are diminished, are the result of undercurrents of greater force than those at the surface.

It is proper to remark, that it was only in the Mississippi, and its deep tributaries and outlets, that the under-velocities were found to exceed those obtained from the surface floats. On repeating the same experiments in shallow mountain streams, of quick descent, the law commonly recognised was found to prevail, and the surface floats passed quickly ahead of those which were attached to lines suspended at any depth beneath the surface.

OF THE VOLUME OF WATER DISCHARGED BY THE MISSISSIPPI.

It was an object of solicitude, on the part of the writer, to ascertain from actual measurement the volume of water discharged by the Mississippi at the height of the flood of April, 1851. But, at the moment when the river was thought to have reached its highest mark, the weather proved to be unfavorable for such experiments, which can only be correctly made at times of perfect calm. The least motion of the wind affects the velocity of the float and vitiates the result. Before suitable weather again occurred the water had receded below New Orleans, where the measurement was made, about six inches.

In that condition of the river, when the surface had fallen six inches, the volume discharged at a point eleven miles below the city, and below all the crevasses then running, was found to be 979,240 cubic feet per second. This measurement was made the 16th April, 1851.

Ten days after this gauging was completed, the weather proved again to be perfectly calm, and the opportunity was seized to ascertain the discharge a short distance below the mouth of Red river. The water had then receded at that place $2\frac{3}{10}$ feet from the highest point attained during that flood. The result, in this condition of the surface, exhibited a total discharge immediately below Red river, of 1,054,000 cubic feet per second.

We have, then, the following important results derived from these experiments:

The discharge below Red river was----------	1,054,000 c. ft. per. sec.
The discharge below New Orleans----------	979,240 do. do.
Lost between Red river and New Orleans-------	74,760 cubic feet.

Even in this state of the facts, after the river had fallen $2\frac{3}{10}$ feet at the mouth of Red river, and only half a foot at New Orleans, the discharge below Red river exceeded the discharge at New Orleans, by 74,760 cubic feet per second.

This fact will be hereafter found worthy of special note, when we come to discuss the practicability of defending the country below Red river, as has been often proposed, by simply strengthening the levees. When the water had fallen $2\frac{3}{10}$ feet, the breaches in the guard-banks of the coast were still venting more water than would have sufficed, as we shall find, to raise the surface twelve inches when the flood was at its extreme height.

But before attempting to discuss this question, it is important to ascertain what volume of water escaped through all the crevasses below Red river at the top of the flood of 1851; and also, approximately, some method to determine the volume of water that will be needed to raise the surface of the river, when in flood, any given height. These questions involve the unknown relations of depths, slope, and velocity of rivers; questions which have been discussed by several able and distinguished writers, but which nevertheless must receive a further examination here.

But it will be useful first to record the actual discharge of the Mississippi in the extreme high water of 1851.

Below the mouth of the Red river, when the surface had receded $2\frac{3}{10}$ feet from its highest mark, the discharge per second was found, by measure-

ments made April 26th, 1851, as already stated, to be---------- 1,054,000 cub. ft. p. sec.
To this add for the diminution of the discharge due to the reduction of the surface, $2\frac{3}{10}$ feet, by a formula to be hereafter presented------ 80,500

And we obtain for total discharge of the high water of 1851-- 1,134,500 c. ft.
This sum, however, expresses only the discharge through the channel. To obtain the total discharge we must include the volume vented by the Atchafalaya. The discharge of the Atchafalaya, below the mouth of the Bayou de Glaise, April 26th, 1851, was---------- 122,700 cub. ft. p. sec.
Add for the diminution of the discharge due to the reduction of the surface there, $2\frac{13}{100}$ feet, at that date---------- 12,800

Total discharge per second of the Atchafalaya during the high water of 1851---------- 135,500 c. ft

Aggregate discharge per second of the Mississippi and Atchafalaya together, at high water of 1851---------- 1,270,000 c. ft.
But the flood of 1851 was three inches lower than that of 1850, immediately below the mouth of Red river. We cannot, therefore, estimate the high water discharge of the Mississippi and Atchafalaya together, at the top of the flood of 1850, at less than---------- 1,280,000 cub. ft. p. sec.

These results apply to observations made on the Mississippi above the Roccourci cut-off, and on the Atchafalaya just below the mouth of Bayou de Glaise.

There is a fact elicited by these investigations, and others conducted at higher points on the river, of great importance in this inquiry, and which has apparently heretofore escaped observation. It is the curious circumstance that the actual channel of the Mississippi—or what may be designated as the *Mississippi between banks*—carries more water, in times of flood, towards the head of the delta, than near the mouth of Red river, or thence to the sea. In other words, more water is discharged by the actual channel of the river immediately below the mouth of the Ohio, or even above the mouth, as high up as Cape Girardeau, than passes by Natchez or New Orleans, or any intermediate point.

The discharge of the Mississippi per second below New Orleans, at the top of the flood of 1851, (from measurements taken June 16th, and corrected for extreme high water,) was---------- 995,000 c. ft.
The discharge through the channel below the mouth of Red river when the surface was highest, June, 1851, was 1,134,500 c. ft.

The discharge of the channel at Memphis, at the top of the flood of May, 1850, as deduced from the report of Mr. Robert A. Marr, United States navy, (see note B,) was-- 958,500 c. ft.

The discharge, one mile below the mouth of the Ohio, June 10, 1851, while the water was yet seven feet ten inches below the high water of 1850, and *nine feet* below that of 1849, and rising about one foot per diem, was ---------- 1,223,000 c. ft.

The discharge about one mile above Cape Girardeau, June 17, 1851, when the water was $4\frac{7}{10}$ feet below the high water of 1844, was---------- 1,025,000 c. ft.

The discharge at this point, above the mouth of the Ohio, during the high water of 1844, must have been at least---------- 1,200,000 cub. ft. p. sec.

These quantities, it will be observed, are in all cases the volumes which flowed down between the banks of the river, and are exclusive of the waters of overflow which enter the swamps above and feed and maintain the floods below.

If we compare the volume discharged in 1851 below the mouth of the Ohio, while the flood was yet nearly eight feet below the high water of 1850, with that known to have passed Memphis at the top of the flood of 1850, we will have data fully to justify the conclusion that more than forty per centum of the volume discharged by the channel immediately below the mouth of the Ohio, passes over into the swamps of the southern counties of Missouri, and escapes the measurements at Memphis. And, in order to form a correct judgment of the masses of water to be dealt with, in the attempt to control the floods of this river, it must be further observed that a great volume also leaves the channel of the Mississippi *above the Ohio*, and passes around through the swamps of Missouri, and consequently escapes even from the measurements below Cairo.

No effort has yet been made to ascertain by direct measurement the volume of water which in times of flood finds its way through the swamps on either side of the river; though this is indeed a very important element in the present inquiry. It was too late in the season for the writer to undertake that work, after he had ascertained its true bearing upon the subject on which it was his duty to report. To do it properly, preparatory surveys should be made across the swamps before the flood comes down, so that the wave might be traced and the volume of overflow determined from point to point, as it advances.

The quantities which are here stated, differ widely from the current estimates of the high-water burden of the Mississippi. But as they result from careful soundings, and simultaneous observations upon the velocity at each point where the depth was taken, so as to divide the section of the river into numerous portions of which the area and velocity were known, they cannot possibly deviate materially from the precise truth.

LAWS OF DRAINAGE.

Several foreign writers on hydrauliques have published formulæ derived from experiments, to exhibit the relations between the depths, slopes and velocities of running streams. But their various equations are almost all derived from each other, or built upon the same observations; while these observations, limited in number, have been made on streams of very small

dimensions. Where they are applied to great rivers, like the Mississippi or Ohio, they fail to give results in close agreement with the recognised facts. It has therefore been deemed advisable, indeed necessary, to derive new and better formulæ from a wider range of experiments—embracing great rivers of gentle slope in full flood, and passing from those to smaller streams of abrupt descent, and in various conditions of their channels. But great difficulties were encountered in the attempt to frame such a formula from observations on the flow of the Mississippi. The movements of this great river are remarkable, and need to be carefully studied before the resulting law can be confidently applied. The river descends on an average slope of about three and a quarter inches per mile, and the mean velocity of its current is, of course, due to that slope. Yet it not unfrequently happens, that while the mass of the water which its channel bears is sweeping to the *south* at a speed of four or five miles per hour, the water next the shore is running *to the north* at a speed of one or two miles per hour.

It is no unusual thing to find a swift current and a corresponding fall on one shore towards the south, and on the opposite shore, a visible current and an appreciable slope towards the north. In other words, the water is often running rapidly *up stream* on one side of the river, while sweeping with equal or much greater rapidity down stream on the opposite side.

It is obvious, therefore, that no single or merely local observation on the rate of descent of the stream can be depended on for the determination of that element of an equation. The apparent slope is at every point affected by the bends of the river, and the centrifugal force acquired by the water in sweeping round the curves, and by the eddies which form on the opposite side, under the salient angles.

The surface of the river is not, therefore, *a plane*, but a peculiarly complicated warped surface, varying from point to point, and inclining alternately from side to side.

To neutralize in some degree the effect of such variations on the littoral measurements of the slope, levels and soundings were taken at different points along the shore not very remote from each other, and mean slopes, depths and velocities derived from many observations. As a check to the results, and a guard against material error, the average slope, depth and velocity was obtained for considerable distances, embracing many bends of the river. And as a further check, the slopes, depths, areas and velocities of the tributaries and outlets of the Mississippi, and of various small mountain streams, were collected and compared. A formula was then sought which should express the maxima or central velocities, in terms of the slope and maxima depths of each of these various streams.

The equation produced by these investigations is here submitted, with the observations from which it was derived, and its application to each set of observations.

Let d represent the maximum depth of the river, in feet, at the place of observation; f, the slope of the surface, in feet per mile; v, the velocity of the central surface current, in feet per second: then the formula proposed is

$$v = \frac{8}{10}\sqrt{df} + \frac{df}{20}.$$

The application of this formula to many of the observations, with the amount of discrepancy in each case, will be found in note C.

It was further ascertained, from numerous observations conducted with much care, that the *mean velocity* of a great river, in a straight channel, is

about eighty per cent. of its maximum velocity, as has been obtained by De Prony and others, for smaller streams.* This proportion is close enough for any practical application needed in this paper; it is, probably, as close a general approximation as can be made in the premises.

There is no necessity of any formula to determine the actual discharge of the Mississippi for any given height of flood or position; that has been done, as far as is necessary for any practical purpose, by direct measurement But it is necessary to have some means of determining approximately what will be the increased height of a flood, due to any given increase in the volume discharged, when the general dimensions and slope of the river are given.

The formula above will be applicable to this object, and will be frequently referred to in the course of this report. That formula expresses the value in feet per second, of the central surface velocity. Eight-tenths of that value is the approximate mean velocity of the whole section; which being multiplied into the area of the section, in feet, will show the discharge in cubic feet.

It will be expedient here to make two applications of this formula, assuming for the constants, dimensions corresponding with the general features of the Mississippi from Donaldsonville to Red river. We will find, by referring to the two preceding tables, that the general mid-channel depth, or the value of d, may be fairly assumed at one hundred and fifteen feet; the general width of surface at about 3,300 feet; the general slope, at high water, at $\frac{25}{1000}$ of a foot per mile; and the average area of water-way, at 215,000 square feet.

By substituting these quantities in the formula, we shall have for the usual mid-channel velocity at high water,

$$v = \tfrac{8}{10}\sqrt{115 \times \tfrac{25}{1000}} + \frac{115 \times .25}{20} = 5.73 \text{ feet per second.}$$

The mean velocity should be eight-tenths of this sum, or

$$v = 4.584 \text{ feet per second.}$$

The discharge per second will then become

$$D = 215{,}000 \times 4.584 = 985{,}560 \text{ cubic feet per second.}$$

But, if the surface should now rise 12 inches higher, in consequence of an increased supply of water, the value of d will become one hundred and sixteen feet; the slope, or value of f, will be $\frac{254}{1000}$ feet, and the area of the average section will be increased to 218,300 square feet.

By substituting these quantities in the formula, we obtain for the velocity in mid-channel way,

$$v = \tfrac{8}{10}\sqrt{116 \times .254} + \frac{116 \times .254}{20} = 5.8156 \text{ feet per second.}$$

The mean velocity is therefore, in this case,

$$v = 4.6525 \text{ feet per second.}$$

The area of the channel, when the depth is increased one foot by the elevation of the surface, is also increased, and becomes

$$A = 215{,}000 + 3{,}300 = 218{,}300 \text{ square feet.}$$

The discharge per second will be, in this case,

$$D = 218{,}300 \times 4.6525 = 1{,}015{,}640 \text{ cubic feet per second.}$$

* The precise figures given by De Prony are, $v' = .8164580$; but the writer pretends to no such accuracy.

Comparing these results, we perceive that when the river is at its usual high-water stage, under the circumstances assumed for the example, the discharge per second is---------- 985,560 c. feet.
And when raised twelve inches higher, by any accidental increase of supply, the discharge must be---------- 1,015,640 c. feet.
From which we deduce for the volume which must be supplied to the channel when in full flood, in order to raise the surface one foot from Red river to Plaquemine, per second 30,080 c. feet.

In applying this formula, however, it is proper to observe that there are two considerations which operate to increase the volume that would be required to produce this increased elevation. When the river is at or near its highest mark, it overflows long strips of level ground between the natural bank and the levee, where there is a sensible, though inconsiderable, motion. This increased area will assist in venting a part of the increased supply.

Again, when the river is rising, the slope of the surface at the point where the rise is progressing, is materially greater than the slope of the surface when at its highest limit, and still greater than the slope which has place after the water has begun to recede. The effect of this consideration upon the velocity and discharge of a river, in cases of rapid rise, is frequently very great. It often happens, at the beginning of a flood in the upper part of the Mississippi, that the water rises at the rate of three or even four feet in twenty-four hours. The average velocity before the rise may be assumed at two and a half miles an hour. The water, therefore, travels at the rate of sixty miles a day. Consequently, when the first signs of the flood are visible at a point sixty miles below the mouth of the Ohio, it may have risen three or four feet at the mouth; and the average slope must have experienced an increase, in that space of sixty miles, of $\frac{1}{6}\frac{1}{0}$ of a foot per mile—which is about one-fifth of the slope of the river before the flood commenced. It is true that, in the lower part of the river, and when the wave has nearly reached its highest mark, the water rises much more slowly, and the increase attributable to this cause is far less serious, than in this example. But even in this case the effect will be perceptible; and it will not therefore be prudent, in the judgment of the writer, to estimate the increased volume needed to raise the surface one foot in extreme high water, at a less average than 35,000 cubic feet per second.

This is submitted as a mean result, applicable only to the general or average dimensions of the lower Mississippi. No rule can be given which will apply to every position; for the width, depth and area of the stream are most variable; and as the same volume of water must pass through different sections, its velocity, both surface and mean, must be subject to continual change.

OF THE CREVASSES.

From the description which has been given of the delta, it will be easy for those not familiar with the formation of the valley of the Mississippi, to appreciate the danger to which the population there is continually exposed in times of flood, from the inundations of the river, consequent on the giving way of the protecting levees. The condition of things in high water is faithfully represented in the diagram, fig. 1. The surface of the river is

there shown to be from five to seven feet above the surface of the cultivated fields on its borders: and the water is prevented from sweeping over these fields by artificial embankments, which now extend in continuous lines on both sides of the river, from below New Orleans to the mouth of the Arkansas—a distance of about 600 miles. These embankments, in most cases, are maintained by the individual proprietors: so that the security of the property of every planter depends both upon his own vigilance and experience and those of his neighbors. This vigilance is not always sufficient for the protection of the country: and it will hereafter be shown that no care can ever be sufficient to guard against the occurrence of overflows; that breaches through the present levees are unavoidable: and that, indeed, such breaches are the necessary safety-valves for the escape of the surplus water; and must continue to have place until other and less costly provision is made.

The water of the Mississippi now usually rises to a level not more than twelve inches below the tops of the levees, and four or five feet above the general surface of the ground immediately behind the levees. This ground slopes off at the rate of three or four feet per mile from the levee to the swamps, or until it reaches a level from fifteen to twenty-five feet below the high water surface of the river. This is shown in the wood-cut below, which is a correct representation of the four and a half miles extending from the Mississippi at Bonnet Carré, about forty miles above New Orleans, to Lake Pontchartrain.

If the levee should here give way, as has already happened, the water would, of course, rush through the breach with the velocity due to the depth of the column and the slope of the plane in the rear of the embankment. With a depth of six feet and a slope of three feet per mile—numbers corresponding with the circumstances of the Bonnet Carré crevasse, as near as any that can now be obtained—the velocity of the current passing from the river into the fields will be at the surface, by the formula,

$$v = \tfrac{8}{10}\sqrt{3 \times 6} + \frac{3 \times 6}{20} = 4.30 \text{ feet per second.}$$

The area of the Bonnet Carré crevasse, when running, appears by measurement to have been—if we take the entire width of the levee which was destroyed, and the high-water line of the surface while the crevasse was in full activity—about 43,500 square feet. The volume discharged would appear from these elements to be,

$$D = 43{,}500 \times 4.3 \times \tfrac{8}{10} = 149{,}609 \text{ cubic feet per second.}$$

This is the discharge which we obtain for that great crevasse by using those visible evidences which yet remain. But there is one circumstance which will lead to the conclusion that this crevasse, at no period of its running, gave vent to so great a volume as is deduced from these elements.

A portion of the present gap must have been created after the water began to recede, as the current could not have failed to continue to cut away the levee as long as water continued to pass through the opening with sufficient velocity for that purpose. We have no means to determine what deduction should be made on account of the enlargement of the opening during the fall of the water; but it is quite probable that 100,000 cubic feet per second is the extreme estimate to be admitted for the discharge of this crevasse when at its maximum.

Many other crevasses were discharging simultaneously with that of Bonnet Carré during the winter and spring of 1850; but there are no means of ascertaining the total discharge through all the breaches for any portion of

that period. It has been estimated by a distinguished engineer of New Orleans, M. Buisson, on the best data that he could obtain, that at one period no less than 536,778 cubic feet per second was drawn off laterally by the crevasses of that year. But as this estimate seems to have been made by using the actual breadth of the opening, as it was measured after the flood had subsided, it is probably in excess, a part of the breach having doubtless been created during the fall of the water.

But, if we make the most liberal allowance for that consideration, and assume that one-half of the total width of opening was produced during the subsidence of the waters, we shall still have a discharge of nearly 300,000 cubic feet per second for the crevasses of 1850, resulting from the facts exhibited by M. Buisson.

It is, however, quite impossible now to ascertain the discharge of the crevasses of past years with any approach to certainty. But in 1851, when there was no remarkable flood in the Mississippi, the writer had the means of making an approximate estimate of the volume discharged by all the crevasses then in activity below the mouth of Red river.

To arrive at this volume, an attempt was made to measure the discharge of the Mississippi river below the mouth of Red river, the lowest of its tributaries, and again below all the crevasses at the time of extreme high water. Then by taking the difference between the results, it was hoped to obtain an expression for the volume lost by the way. But impediments to the perfect execution of this plan occurred, and the water had receded somewhat, at both points from its highest mark, before the measurements could be completed. We are obliged, therefore, to make some allowance for this fall, in order to obtain the true discharge at either point.

The following are the results deduced from the measurements:

The discharge of the Mississippi below the mouth of Red river, per second, at the top of the flood of 1851, was	1,134,500 c. feet.
The discharge below New Orleans during the high water of 1851	995,000
Lost between Red river and the place of observation, eleven miles below New Orleans	139,500 c. feet.

This loss is attributable partly to the discharge of the crevasses below Red river, and partly to that of the two natural outlets, the bayous Plaquemine and La-Fourche, which are still in activity.

The high water discharge of the Plaquemine was found by measurement to be	28,500 cubic feet per second.
That of the La Fourche	10,200 " " " "
Total discharge of the two natural outlets	38,700 cubic feet per second.

Now, by deducting the discharge of these two natural outlets from the total loss of water between the mouth of Red river and a point eleven miles below New Orleans, we obtain the discharge of all the crevasses at the time of the extreme high water of 1851. This discharge was 100,800 cubic feet per second. Neglecting the fraction, we may assume that in 1851 a volume equal to 100,000 cubic feet per second, or about ten per

cent. of the total discharge of the Mississippi at New Orleans, escaped from the channel, and passed through the vents in the artificial levees below Red river.

These measurements were made in the best possible conditions of wind and weather; and though all such computations and measurements are liable to some error, it is believed that these may be relied on as accurate enough for any practical deductions which it may be desirable to draw from them.

But, we have already seen that if the volume discharged by the river at high water were increased 35,000 cubic feet per second, the surface would be raised below Red river about one foot. We cannot, however, thence conclude, that if the crevasses which, as we have seen, discharged 100,000 cubic feet per second, had been all closed up, the water would have risen, at any point, within a fraction of three feet. These crevasses were distributed all along the coast, and many of them were too far below Red river to affect the height of the floods materially there; while an increase of more than 35,000 cubic feet per second would be required to raise the surface twelve inches at New Orleans. It is, indeed, impossible to say with certainty what would have been precisely the increased height of the flood of 1851, at any point, if the levees below Red river had been high enough and strong enough to support the weight of the water which was upon them. The writer can only express the opinion, the correctness of which he cannot fully demonstrate, that if the levees had withstood the pressure, the flood of this year would have been about two feet higher at and near Baton Rouge, than the line which it actually attained; and, consequently, if the crevasses had not occurred to vent the water, the levees of lower Louisiana, which were only ten or twelve inches above the flood, must have been generally overflowed. It follows, therefore, that if it be determined hereafter to rely exclusively on levees, and prevent the occurrence of crevasses altogether, these levees, to sustain a flood like that of 1851, must be made, from Red river to New Orleans, competent to resist an increase of ten per cent. in the volume discharged by the river; or, in the view of the writer, at least two feet higher than the present banks. This condition, it is apparent, would involve the entire re-construction of the embankments on both sides of the river; and hence, *in order to retain merely the crevasse water of this year*, the levees must be entirely re-constructed, and made two feet higher; or new outlets must be opened competent to vent 100,000 cubic feet per second—which is more than the volume now drawn from the Mississippi, at high water, by the Atchafalaya itself.

LOCAL CHANGES AND IRREGULARITIES.

Close observers of the Mississippi sometimes remark singular and often inexplicable phenomena attending its floods and movements; and, in consequence of the insufficiency of the facts which are known, to account for the irregularities, it is customary to regard this river as a river *sui generis;* which sets at defiance the acknowledged laws of hydrodynamics, and disappoints calculations based on recognised principles. But these irregularities are always traceable to some sufficient cause, when carefully investigated and all the attendant facts are elicited.

A *crevasse* will frequently produce a material depression at the point where it occurs, and also both above and below that point. If this crevasse

happen to be closed up before the next flood approaches, there will, of course, be an apparent rise in the water where the previous depression had been observed.

A *new levee*, which excludes the water from a large area of swamp previously filled by the overflows, will cause an engorgement of the stream at that point, and a consequent rise, which will extend over a considerable space above and below the new work.

The *bends* of the river, as has been shown, cause its surface to assume a distorted shape. Where the water impinges against the concave shore of a bend, its surface rises a certain amount—the height due to the velocity of impact. But the tendency of the stream is forever to elongate its channel, and make compensating deposites on the salient angles. These points sometimes undergo material changes of position. Sand-bars are washed away from the jutting angles in some cases, and new deposites are formed in other positions. The current, consequently, impinges afterwards against a bank where there was formerly an eddy, and the slope of the surface was up stream. The direction of the current being thus reversed, there will necessarily be a change in the high-water mark produced by an equal flood, which may, in extreme cases, under like circumstances in other respects, be almost equal to the sums of the heights due to the reversed velocities. From this cause alone, having its origin in the tortuous course of the stream, there must occasionally occur local changes of more than twelve inches in the heights of equal floods, or floods produced by equal volumes of water.

The *wind* is another fruitful source of local irregularities. A prevailing breeze in a given direction might produce results which would defy speculation, unless its effects were investigated as a distinct study, with the aid of correct maps of the river.

The writer once had an opportunity, in running a test level along both shores of Chautauque lake, a narrow sheet of water, to detect a variation in the surface of more than eight inches in twenty miles, produced entirely by a continued but moderate breeze. Indeed, such effects are of daily observation on all lakes and tide-water streams. But in the channel of a winding river, like the Mississippi, they are much greater than in ordinary cases, and much more difficult of detection. The same wind that increases the height of a flood in one bend will reduce its height in the next; so that while the flood at a given point is even with the flood of a previous year, it may be found at some place a few miles distant, under circumstances precisely similar in other respects, many inches higher or lower than the mark of the previous flood.

This may be readily explained by a diagram (fig. 3) which is taken from La Tourette's map of *Millikin's bend*, above the mouth of the Yazoo.

Here the course of the Mississippi is descending from A to F. The arrows WW, represent the direction of the wind. The effect of this breeze, acting upon the surface of the water along the reach from E to D, will be to retard its flow and cause an accumulation in the bend at D; while at the same time the effect of the same breeze, acting along the reach from C to D, will be to hasten the surface forward and increase the accumulation at the same point—in the bend D.

But, in the mean time, this same current of air, driving the surface water forward from C to D, pushes it also back from C, in the reach BC, and tends to retain it at B. The water is thus driven away from C, along both the channels CB and CD, while it is driven forward by the same wind to D,

along both the channels CD and ED. The consequence will be that while this wind prevails, there will be a decided accumulation of water at D, and a material reduction of the surface at C. The floods at these points will not correspond in height with a previous flood when the direction of the wind was different, and much less if its direction in the previous flood were reversed.

In a river as tortuous as the Mississippi, every wind that blows, no matter what may be its direction, must produce such discrepancies in some parts of its course. And in constructing a profile of two consecutive floods, as has been attempted for the floods of 1850 and 1851, in this report, we must not be surprised if we sometimes encounter, in close investigations, singular discrepancies.

The *smaller tributaries* are also, frequently, the cause of such irregularities as are here under consideration. A very inconsiderable stream discharging suddenly for a few days, or hours even, a large volume into a full river, will produce a material elevation as well above as below the mouth of the tributary. Consequently, before attempting to explain the cause of a local variation in consecutive floods, we must know the condition of the nearest tributaries at the respective periods.

It is not the intention here, however, to enter into a minute discussion of the uninteresting and useless details of the recent floods in the lower Mississippi. The great object before us—to contrive measures for the protection of the delta from overflow—is not to be attained by a microscopic examination of such local phenomena. The solution of this problem turns upon other and greater elements, which we are now in a position to discuss with profit. The first step in seeking a practical result is to determine with certainty the prominent causes of the increasing inundations, and to obtain the means of estimating correctly the respective values of such causes.

PART II.

CAUSES OF THE INCREASING OVERFLOWS OF THE MISSISSIPPI.

The object of the investigations which have been ordered, of the condition of the delta, is to decide upon some appropriate mode of protecting the country against the annual inundations of the river. To be able to provide a remedy for this great evil, it is necessary in advance to satisfy the mind of the causes which produce the evil. These causes, it will now be shown, are essentially *artificial*. The floods are increased in frequency and in height by artificial means, and it is not unreasonable, therefore, to look for relief to artificial appliances.

Of the various influences to which the increasing elevation of the recent floods of the Mississippi is to be referred, there is but one that can be regarded as belonging to the class of *natural causes*. This exception will be considered first.

OF THE PROLONGATION OF THE DELTA.

It is a popular belief that the bed of the Mississippi is gradually *rising*, and to that assumed cause is not unfrequently attributed the constantly

increasing height required for the protecting levees. But this belief can be traced to no better evidence than the fact, that certain points, which formerly exhibited deep soundings, have subsequently become shallower—a circumstance which is attributable altogether to the shifting character of the shores and bottom of the river. As consequences of the changing and movable character of the soil through which the Mississippi flows, points which are at one period curved, subsequently become salient: shores that at one time wash and cave in, at a later date fill up; places which, during one period, are gradually growing deeper, at another become less deep, and to the sounding-line indicate an elevation of the bed. There is, in fact, no evidence of any change in the general level of the river's bed, beyond what may be inferred from the evident prolongation of the delta, the lengthening out of the course of the stream, and the consequent diminution of the plane of descent. But this elevation of the bed is not indicated by any increased depth of water, though it must of necessity occasion a corresponding elevation of the surface. Any increase in the height of the floods, produced by a given body of water discharged in a given time, beyond what may be justly attributed to this extension of the delta, must therefore be sought in other adequate causes.

It is important, then, to ascertain what influence the progress of the land into the gulf may have upon this question, in order to be able to judge of the ability of society to contend permanently against this, the only visible natural cause of increasing floods. This is a subject upon which we are compelled to reason without the aid of precise and satisfactory data. The writer is unwilling to admit a mere speculation in his report, but in this case it cannot well be avoided.

At whatever point we place the original head of the delta, at the time when the sea flowed up to that point, there must have been a fall in the Mississippi there, or in that vicinity, equal to the whole descent from the present level of the river at that place to the level of the ocean. Now, the first chain of rock which is supposed to form the bed of the Mississippi, is found at the village of Commerce, about thirty miles above the mouth of the Ohio, where the rocky hills approach the shore on both sides of the river, and are possibly connected by a bed of rock in the bottom of the channel. The low-water surface of the river at this "Chain" is about two hundred and eighty-five feet above the Gulf of Mexico. It follows, therefore, that if, at the period when the formation of the delta may be supposed to have commenced, the level of these rocky hills and the level of the ocean were the same as they are now, there must have been, as before stated, a *cataract* above the mouth of the Ohio, with a fall of two hundred and eighty-five feet at low water, or nearly double the actual perpendicular descent of the Falls of Niagara. The water of the Mississippi must have plunged over this cataract, or over great rapids, directly into the sea, which, by the supposition, then flowed up beyond the mouth of the Ohio. In the course of time, the sea must have been filled up by the sediment brought down by the Mississippi river, and the Mississippi has thus gradually risen upon the bed formed by its own deposites.

As the deposite has been pushed out into the sea, the slope of the river has progressively diminished; and as the slope of the plane has diminished, the surface of the river has risen, and the bottom, of course, has also been in like manner elevated.

It is not contended here that the true head of the delta is demonstrably

to be found above the mouth of the Ohio. It is quite possible that there were great rapids only here, and other rapids nearer the sea, at one or more points lower down the stream. The force of the argument which is made will not be in the least impaired by an erroneous location of the original head of the delta, and it is no part of the present purpose to engage in irrelevant geological speculations.

It will be assumed, therefore, that the head of the delta was once above the mouth of the Ohio, and two hundred and eighty-five feet above the level of the sea; and that the depth of the sea was then about the same where the delta now is, as the present depth of the Gulf of Mexico within a few miles of the Balize. That since that period the delta has been formed by the annual accumulation of sediment brought down by the stream and deposited in the sea. The inevitable conclusion must then be, from this hypothesis, that the slope of the plane must have been, at various periods, as represented in the annexed diagram, fig. 4.

Originally, or at some period anterior to the formation of the delta, the river sloped off abruptly, forming a cataract or rapids, from the hills at Commerce to the point A; subsequently, the whole space embraced in the triangle H A B, became filled up by sedimentary accretions, and the river sloped off from H to the mouth of the Arkansas, with a descent represented by H B, more than twice as great as its present rate of descent. By degrees, and in the course of ages, these accumulations reached the mouth of Red river, at C; and in more modern periods were extended on to the present shores of the gulf, at D.

It is manifest, therefore, that while this process is going forward, the surface of the river must be rising, and that, as the surface is elevated, the bottom must also simultaneously rise. In fact, it is the elevation of the bed which causes the rise of the surface.

Nothing can be more palpable than the gradual elevation of the surface of the Mississippi, in so far as it is attributable to this cause; and it is therefore most manifest, that while the river is thus rising above the sea, and the levees so confine the water to the channel as to prevent simultaneous deposites upon its banks, the floods will gain upon the embankments, and *ultimately* overtop them.

To this extent, it must be admitted that the rise of the bed of the river will forever be a cause of increasing inundations. But it remains for us to ascertain whether this cause can be sufficient to account for any portion of the present sufferings of the population of the delta, or whether its operation has not been too slow even for detection within historical periods.

The area of the delta is not accurately known, but it will be estimated in this report, in the absence of data from which to make a more accurate approximation, at forty thousand square miles.

It is known from actual survey, that the mouth of the Ohio, at low water, is two hundred and seventy-five feet above the level of the sea; and it has been ascertained by the levels taken under the direction of the writer, that the slope of the Mississippi near the mouth of the Ohio is about five inches per mile, (see note D.) The total elevation then, at Commerce, is, as stated, very nearly two hundred and eighty-five feet above the sea. Adding for the average height of the banks thirty-five feet, we have three hundred and twenty feet for the level of the Mississippi bottoms near Commerce, above that of the Gulf of Mexico. But, as the plane of the delta slopes off gradually and uniformly from this village to the gulf, the average level of

the whole area will be but about one-half of this height, or one hundred and sixty feet above the sea; and if we should make a reasonable allowance for the greater breadth of the plane near the sea, than nearer its head, it is probable that one hundred and forty feet would be found to be a very fair estimate of the average depth of the whole deposite above the level of the tide.

Now, it has been found by the experiments of Professor Riddell at New Orleans, conducted with great care and often repeated, that the mean bulk of sedimentary matter transported by the river, when solidified into coherent earth, is about $\frac{1}{3000}$ part of the volume of the water in which it is suspended. If now, superadded to these data, we could obtain the total annual discharge of the Mississippi and its tributaries, we would command all the facts necessary to compute approximately the amount of the annual deposites brought down by the current. But there are no sufficient observations to enable us to estimate the total discharge of the Mississippi and its outlets for any one year. This volume has been estimated by Professor Forshey, from numerous observations of his own, made through a long series of years, at an average of 12,250,000,000,000 cubic feet; and for the year 1849 at 13,338,040,000,000 cubic feet; and these estimates have been adopted by numerous engineers who have discussed the great problem of controlling the Mississippi. But though the period embraced by the investigations upon which this report is founded, did not permit an attempt to estimate the aggregate annual drainage of the Mississippi valley, with any approach to accuracy, the observations which were made are, nevertheless, sufficient to justify the conclusion that the annual discharge of the Mississippi and its natural outlets, when fully ascertained, will be found to average at least fifty per cent. more than the received estimate, or probably not less than 21,000,000,000,000 cubic feet per annum. This volume, though by no means regarded as accurate, will be assumed as the basis of the conclusions to be drawn in the matter before us, where great precision is not at all needed.

Now, it has already been stated on the authority of an accomplished manipulator, (Professor Riddell,) that the $\frac{1}{3000}$th part of the total annual discharge of the river consists of sedimentary matter. Whence we find for the annual deposite of sediment, or the volume annually left in the gulf at or near the mouth of the Mississippi, 7,000,000,000 cubic feet.

This mass of material would be sufficient to raise to the height of one hundred and forty feet a portion of the delta equal to $1\frac{8}{10}$ square miles. To form the whole delta, or that portion thereof which is now above the sea—covering, as estimated, 40,000 square miles—would have required a period of $\frac{1}{1\cdot8} = 22{,}222$ years.

This result is, of course, based upon the supposition that this vast formation is the product of the forces now at work—the visible causes now in action.

If the delta has resulted from the deposites of the river, then it is demonstrated from these facts—not minutely ascertained, but nevertheless near enough to positive accuracy for any desirable practical conclusion—that more than 22,000 years have been occupied in the formation of that portion of the delta which is now above the plane of the sea.

But it is known that when we proceed a few leagues out into the gulf, we find soundings of more than fifty fathoms, and over extensive portions of the gulf, of more than one thousand feet. Though we cannot prove that this, or any other given depth, was originally maintained up to the assumed

head of the delta, it is, nevertheless, not an unreasonable supposition, that, at periods anterior to the commencement of the deposite, the bed of the gulf sloped up uniformly from its present depth near the Balize to the shores then found above the mouth of the Ohio. This under-water deposite must therefore have required a mass of matter more than equal in volume to that now found above the surface of the ocean. Hence we are authorized to conclude that the total formation known as the delta of the Mississippi, if it be, as is scarcely deniable, the result of sedimentary deposites, has required a period for its formation by the river, of something like 45,000 years.

Now the average length of the delta, from north to south, is about five hundred miles; and if its total formation has required a period of 45,000 years, each mile of the progress of its shore into the sea has consumed an average period of $\frac{45000}{500} = 90$ years.

This is to be regarded as a maximum or an extreme estimate of the average march of the whole coast, southwardly from the beginning of the deposite: but it is certain that the progress of the entire front, in later periods, must have been much less rapid, both in consequence of the increase of the depth of the gulf as we proceed towards its centre, and the greater longitude of the coast, which has, in modern days, been advancing seaward.

It will be observed that this result applies to the extension of the whole gulf shore, from the mouth of Pearl river to Vermillion bay, in a southwardly direction. But, immediately at the point where the Mississippi enters the gulf, it pushes out a narrow peninsula, with numerous mouths, and for a period makes its deposites opposite to these mouths, and laterally therefrom, to only a very limited distance on either side. While it occupies this position, as at the present period of its history, and while all the material which it bears is used in forming this narrow peninsula, the apparent progress of the land upon the sea is much greater than the actual average advancement of the whole front of the delta—which can only be set forward by the shifting of the immediate mouths of the river.

There appears to be plausible evidence of a present local progress of the immediate embouchure of the Mississippi, of not less than one mile in twenty years, showing a local or limited march four or five times as great as the average progress deduced above for the whole front from remote periods.

Now it is this local progress which marks the present rate of elevation of the bed of the river.

The level of the river at New Orleans, in times of flood, may be stated to be 13.5 feet above mean tide, and the distance from the city to the gulf at 105 miles.

The average slope of the river from New Orleans to the mouth, at high water, is, therefore, $\frac{13.5}{105} = .128$ of a foot, or $1\frac{1}{2}$ inch per mile.

If that same average slope be maintained as the mouth of the river moves forward—which it will be, very nearly—each mile that the land gains from the sea will involve an elevation of $1\frac{1}{2}$ inch in the high-water surface, and consequently in the bed of the river at New Orleans. This will produce an elevation—while the Mississippi continues to discharge at its present embouchure—of about $7\frac{1}{2}$ inches in the course of a century; which is certainly an extreme estimate.

It is sometimes conjectured that the city of New Orleans is destined to ultimate destruction from the gradual, and, as it is supposed, the visible rise

of the bottom of the river. But it is not easy to detect the danger in any agency to which the assumed catastrophe has ever yet been attributed. There is, in fact, no presumable rise of the bed of the river, but that which is referable to this one cause—the gradual extension of the delta.

The idea which has acquired a certain hold upon public opinion, that an appreciable elevation of the bed of the Mississippi has been produced, and is still going forward, in consequence of the extension of the levees, has no foundation in experience or philosophic deduction. The extension of the levees, it will be hereafter shown, exercises great influence upon the height of the floods; but not, as is supposed, by raising the bed of the river. It is true that by the increased transporting power which the levees give to the river, the Mississippi is enabled to convey greater deposites into the gulf; and thus, in some slight degree, accelerate the formation of land opposite its mouths. To this amount, and no further, the extension of the levees may promote the elevation of the bed: but this is not an appreciable quantity.

It is customary to point to the Po, in evidence of the effect of embanking the coasts of streams in producing an elevation of the bed of the river. And it is assumed that because the bottom of that stream has been greatly elevated since levees were there commenced, the obvious rise of its bed is directly attributable to the levees. But the true cause of the rapid elevation of the bottom of the Po, and of all the rivers that empty into the Adriatic, is to be found in the great quantity of earthy matter which they transport to the sea, and the shallowness of the gulf into which this material is conveyed. This deposite, in the course of twenty centuries, has produced a prolongation of the delta of the Po, estimated at about twenty-five miles, and has converted cities which at the commencement of the Christian era were respectable seaports, into inland towns, at this day twenty miles from the sea-shore.

If we now assume that the town of Ferrara is about fifty miles from the coast, and that the slope of the Po in high water, from Ferrara to the gulf, is seven inches per mile, we will perceive how an extension of the delta twenty miles into the gulf will have brought the tops of the levees above the roofs of the houses in that city.

In the annexed wood-cut, (fig. 5,) F represents the position of Ferrara on the Po as it was twenty centuries ago: M the mouth of the river or the shore of the Adriatic at that period: and M′ the position of the shore at this time—MM′ representing the progress of the delta in the course of two thousand years.

It is obvious from the figure that M *n* will represent the elevation of the bed, or the present height of the bottom of the river, above the level of the sea at the ancient shore of the Adriatic. And if the descent of the Po is now about seven inches per mile, this elevation must be twelve or fourteen feet, and very nearly the same at Ferrara.

If we now add twelve feet to the height of the embankment originally required to protect the ancient town from the floods, we will perceive that the present levees must necessarily be level with, or above, the roofs of the smaller class of houses in the modern city.

In the course of twenty centuries, in consequence of the prolongation of the delta of the Mississippi, no doubt the levees required to protect the city of New Orleans will have risen to a great height also—probably to a height of ten or twelve feet above the actual plane of the streets—unless the river, deserting its present bed below the city, form a new outlet

into Lake Borgne, and transfer its sedimentary deposites into the deep water of the gulf south and east of Ship island. This is a consummation, as we shall see, much to be desired. But it is not those effects that may be witnessed in the course of centuries which it is the intention now to discuss. The present rate of progress of the delta will soon be solved approximately by the coast survey, when we shall have all the material for speculation upon the future geological changes liable to have place in consequence of the prolongation of the peninsula at the mouths of the Mississippi. The present inquiry will be limited entirely to those evils which at this moment threaten the prosperity and existence of lower Louisiana, and the worst effects of which are likely to be witnessed by men now living. The elevation of the bed of the river, consequent on the progress of the delta, is clearly not one of these. That is too slow to concern the present generation.

It is not to the gradual but certain work of nature, in filling up the sea by the deposites brought down from the plains and mountains, that the increasing height of the floods now felt is to be attributed. These, we shall find, are traceable directly to the labors of men, long and still vigorously engaged in draining the waters, by various processes, more rapidly from the country above, and destroying those natural reservoirs which originally protected the country below.

OF THE CUT-OFFS.

Among the causes of the inundations that have recently produced so much loss and distress on the lower Mississippi, in the opinion of the writer, must be enumerated the *cut-offs* which have been made at and below the mouth of Red river. It is true that men of science have denied, and do still contest this point. But the opinion here entertained rests on what are deemed to be the natural laws of the flow of the river, and, moreover, on indisputable results. The theory which is entertained by many intelligent persons, that by shortening the channel and cutting off the bends of the river, the velocity of the current will be increased, the channel scoured out wider and deeper, the floods conveyed more rapidly to the sea, and the surface therefore reduced, is all perfectly true, excepting the practical conclusion.

It is true, that by cutting off a given bend the flood will be hastened forward, and a greater volume will therefore be discharged through the channel in a given time. But it will not be discharged directly into the sea, and thus relieve the river of its burden. On the contrary, the water will be drawn more rapidly from the river above the bend, and the level of the surface there will be reduced; *but it will be precipitated more rapidly into the river below the bend*, and the surface there will be necessarily raised. This is precisely the error which led the State of Louisiana, in face of the sound advice of several eminent engineers, into the unfortunate experiment of cutting off the Raccourci bend, in 1848.* The velocity of the river, it was contended, would be increased and the height of the floods therefore reduced. They were reduced *above* the bend, from whence the

* It is due to Colonel William S. Campbell, civil engineer, to say that he constantly resisted this work before the legislature; and to Colonel P. A. Hebert, at that time the chief engineer of Louisiana, to record that he also opposed it as long and as warmly as an officer of the State government could oppose the will of the legislature.

water was more rapidly drawn; but they were increased *below* the bend, where it was more rapidly thrown.

The reason in favor of shortening the channel would have been sound if it had been proposed to cut off a part of the lower portions of the river, as will be proposed hereafter in this paper, and admit the water into the gulf at some point further from the sea than its present mouths. The effect of such a course may be appreciated by a diagram. (See fig. 6.)

Let M′ be the present mouth of the river, near the Balize, and S′ M′ the present slope of the surface of the stream at high water.

If we cut through the natural levee which now confines the water, and let the river into the gulf at M, fifty miles higher up, we shall obviously reduce the surface at M an amount equal to M m—the whole of the descent in the lower fifty miles of the river, or about six feet. The surface of the river will then be found in the new line S M, *below* that which marks its present slope.

But a very different state of facts results from cutting off a bend of the river in the upper portions of its course. The Mississippi descends from the head of the delta to the head of tide in obedience to what may be designated as *the law of uniform descent.* The plane upon which it rests slopes down to the ocean, as already shown, at the average of eight inches per mile. But the Mississippi flows on tranquilly and smoothly, in whatever direction it chances to take, seeking every point of the compass—sometimes parallel with, and sometimes at right-angles to the plane which supports it; sometimes directly down that plane, and sometimes in a direction directly opposed to that of its descent: but always with the same almost uniform and unbroken slope. That slope averages at high water a little over $3\frac{1}{4}$ inches per mile, from the mouth of the Ohio to the vicinity of the tidal influence.* There are of course local irregularities caused by the great flexures of the river, and by sand bars, which produce occasional acceleration, and even littoral *inversions* of the current: but these are local and limited influences, and can scarcely be regarded as exceptions to the general law of the river's motion.

Now, when a great bend is cut off, as at Raecourci, below Red river, the total descent around the bend—which was in this case $4\frac{1}{2}$ feet at high water—is suddenly concentrated in the narrow neck, of less than one mile, across the bend. The moment when the cut-off is made, therefore, the slope of the river will assume the form represented in the diagram below.

Here the fall from *a* to *b*, a distance of one mile across the neck of the bend, is four and a half feet, and consequently the water rushes through the artificial opening, with a speed due to that descent, and to the depth of the new channel. (See fig. 7.)

A few days suffices to wear away the soft material which confines the water, and the reach of the river above is rapidly drained off in some degree, by the increased descent of the surface, and discharged into the reach below. The new surface, therefore, speedily assumes the slope of the line *a′ b′*—the excess drawn from above being deposited below. The increased draught through the cut-off thus draining the river above more rapidly than it was accustomed to discharge itself around the curve, the surplus water is

* In this, as in all other computations, the writer is compelled to adopt the distances as reckoned by the river pilots.

necessarily thrown into the river below more rapidly than the channel there had been accustomed to receive and discharge it. The consequence of this increase of supply must, obviously, be a sufficient accumulation below the cut to produce that increase of depth and speed which is necessary to enable the channel there to vent the additional supply sent down, as fast as it is received.

The writer is aware that there is, along the Mississippi, a prevailing opinion in favor of cutting off the great bends and shortening the channel. The interests of the navigation, and of those who depend on the navigation, seem to be promoted by it. But it is an *improvement* of the most dangerous description—one of those things which can be accomplished easily, and without skill, and therefore always liable to be attempted. Besides, experience has shown conclusively that after a cut-off has been made, the lands above are rendered less subject to inundation than they were before, and there is consequently a strong interest always ready to encourage an enterprise that will bring certain relief to a few, even though it may be contended that this relief to them will be disastrous to their neighbors. They contest this fact on the authority of scientific writers; and the minds of men are easily convinced of the soundness of arguments which it is their interest to believe.

We cannot hope to relieve ourselves of the sad effects of these violent changes of the course of the river, by the method proposed in a late report to the Commissioner of the Land Office,* viz: to commence at the Gulf of Mexico, and straighten the river from the sea towards its source; nor by the popular suggestion of compensating for the increased volume poured down through the cut-off above, by making additional cut-offs below, and thus hasten the drainage of the reach below the upper cut-off. There is no opportunity offered by the bends of the Mississippi for any such compensation. The only cut-offs that can hereafter be made with any show of caution are above Red river, and all that are made there will tend to precipitate the water more rapidly upon the beautiful estates from Natchez to the sea.

The increase of the velocity of the current below the cut-offs, in virtue of the reduction of the length of the channel, cannot prevent the increase of the floods, by giving more rapid vent to the water—for this acceleration is itself only a consequence of the increased elevation of the surface produced by the additional supply.

For these reasons the writer deemed it expedient to examine those bends of the river which seem to offer the greatest facilities for the making of cut-offs, either natural or artificial, with a view to ascertain what measures, if any, were needed to prevent their occurrence by the direct working of the river, or by design.

The points to which attention was specially directed, and the general results of the examinations instituted, will be exhibited in this paper, and in still greater detail in a supplemental report. It may be well to state here, however, that one of these points, the Terrapin Neck bend, above Vicksburg, requires immediate attention, to prevent the occurrence of a sudden cut-off, and the overflow of many valuable estates below it.

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* Ex. Doc. No. 68, Senate, 21st Congress, 1st session.

OF THE EFFECTS OF CULTIVATION.

Among the causes contributing to the increase of floods in the rivers of the United States in recent years, it is necessary to include an increased discharge of water due to the destruction of the timber, and the cultivation of territory which was formerly untilled. It is reasonable to suppose that the removal of the forest growth, and the rank vegetation of the virgin soil, will cause the slopes to shed the rain more rapidly into the valleys, and thus produce more sudden and more violent floods than were observed of old.

Indeed, it cannot well be denied that this result must spring from this cause. But, it is not to be overlooked that, at the same time, the removal of the timber gives the sun's rays more direct access to the earth, and thus promotes an increase of evaporation. This increase of evaporation is, of course, at the expense of the drainage; for, as the evaporation increases, the volume of water that finds its way into the streams is necessarily diminished. The effect of clearing the soil of its original growth is thus, at once, to develop two opposite and compensating influences. But it can scarcely be doubted that, as a rule of almost general application, the resultant of these influences will, in the aggregate, be in favor of a great increase of the discharge of the streams, and a material reduction of the evaporation.

But, be this as it may, it is very obvious that the height of the floods is increased by the extension of cultivation and improvement. The increase of evaporation consequent on the exposure of the surface of the earth to the rays of the sun, has place mainly when the sun possesses the greatest power—in the summer season. The effect of clearing the soil of vegetation will, therefore, be to diminish the summer volume, and consequently further to impair the low-water navigation of the streams. But, in winter, when the power of the sun and the resulting evaporation are small, and the rain and snow rest long on the prairies, the necessary effect of removing the timber will be to increase the drainage.

It may therefore be asserted generally, that the effect of cultivation is to increase the evaporation in the summer months, and thus reduce the summer drainage; and to hasten and augment the drainage in the winter months, and consequently increase the height and power of the floods. In short, the clearing of the soil tends constantly to make the water lower in the summer and fall, and the floods higher in the winter and spring.

The area of the Mississippi valley is composed, in the main, of wide extended plains and level prairies, on which, in the original condition of the country, there was little or no timber. Over these plains, the water which falls on the untilled soil is obstructed by the wild grass and bushes, and consequently retained upon the flat surface until it is either evaporated, or slowly passes off into the natural depressions, which convey it through similar impediments to the greater channels of discharge.

But, as population takes possession of the ground, the wild grass is removed and the plough is applied to the drainage. The primitive furrows are so directed as to let off the surface water: and the imperfect drains first opened by the plough, are subsequently enlarged and made the channels into which the lateral ditches are led. The success of the crop depends on the perfection of the drainage; and, consequently, one of the first efforts of every provident farmer, on breaking up the sod, is to relieve the surface of his fields of standing water. But the water rapidly discharged

from these incipient drains meets with impediments in the choked up streams, is held back by fallen timber, and spreads over the bottom land. To save these narrow strips of bottom land, which generally afford the finest pastures, the industrious farmer promptly removes these obstructions from the channel and lets the water off into the country below.

This process, though in reality hardly well commenced, is yet progressing over the valley of the Mississippi at the rate of many millions of acres annually. The aim of every proprietor is to drain his own fields, and let the water pass as rapidly as possible into the creeks and rivulets which are provided by nature to convey it away. But the land upon the great tributaries into which this water passes, is equally valuable; and each proprietor there fortifies himself in like manner against the annual and increasing flood. He also drains his fields with a view to the more rapid discharge of the surface water: throws up embankments across the low places to shut out the flood; and if the circumstances of his situation will justify it, levees in his front and confines the swollen water to the actual channel of the stream.

The immediate consequence of all this is, that the water which, in the original condition of the country, remained upon the surface of the prairies until a portion was evaporated, and a portion absorbed by the earth, to be subsequently given out slowly by the springs, is now hurried along hundreds of thousands of artificial drains into the great rivers which supply the Mississippi.

The effect of cultivation is, therefore, to cause a necessary increase of drainage from all the unwooded prairies of the west. To what extent the floods may be increased by this cause, we have no data to estimate. Yet it is important to be able to form some idea of the consequence which would result from any supposable increase of the general drainage of the country. For this purpose an attempt has been made to estimate, on the authority of popular maps, the actual area of the Valley of the Mississippi, from the source of the distant tributaries down to the mouth of Red river.

The result of this computation is given below, with the remark, merely, that though the areas are expressed as they resulted from the measurements, to the nearest hundred square miles, yet the data from which they are obtained are somewhat uncertain, and the quantities can only be regarded as, at present, the best attainable approximation.

TABLE IV.

Of the areas drained by the tributaries of the Mississippi river.

	Sq. miles.
I. The Missouri river.—The area drained by the Missouri and its tributaries, is	519,400
II. The Ohio river.—The area drained by the Ohio and its tributaries, is	202,400
III. The Upper Mississippi river.—The area drained by the Upper Mississippi, including all the tributaries which come in on the east side above the mouth of the Ohio, and on the west above the mouth of the Missouri, is	184,500
IV. The Arkansas and White rivers.—The area drained by the Arkansas and its tributaries, including White river, is	176,700
V. The Red river.—The area drained by Red river and its tributaries, is	102,200
VI. The Yazoo, Obion, Black rivers, &c.—The area drained by the Yazoo, and all other tributaries coming into the Mississippi on the east side, between the mouth of the Ohio and the mouth of Red river, is	29,300
VII. The St. Francis.—The area drained by the St. Francis, embracing the territory lying between its waters and the Mississippi, is	12,100
Total area drained by the Mississippi river above the mouth of Red river,	1,226,600

A comparison of these results will show with how much more propriety this great river should have received the name of The Missouri, than that which it bears. The Mississippi, where it runs into the Missouri, is charged with the drainage water of an area even less than that which supplies the Ohio, and but little greater than that which is received from the Arkansas and White rivers.

The Ohio is the greatest of all the tributaries of the Missouri; the upper Mississippi is the next in importance; the Arkansas the third, and the Red river is the fourth in the scale. The Ohio comes in at, or extremely near, the assumed head of the delta; and therefore, when the channel immediately below its mouth has been already filled by the discharge from the rivers above, a flood in the Ohio must always produce wide-spread overflow. Yet it is not the Ohio, nor the upper Mississippi, nor even the Missouri, to which the inundations of lower Louisiana are mainly attributable. The water which these upper streams send down is generally absorbed by the swamps or accommodated by the channel of the river. But when this channel is full, or nearly full, and Red river—(the fourth in magnitude of the tributaries)—pours out a flood, the effect is disastrous to all the country below. In other words, it is almost invariably the tributary which discharges nearest to the point where the overflow occurs, that is the immediate cause of ruin. Every observing planter, at or above "the Raft" of Red river, remarks, that the floods of the upper Red river itself are nearly always harmless; and that when the country there suffers, it is not from the waters which have come from the Rocky mountains, but from Little river and the two Cypresses—streams scarcely known to geography.

These facts are important, because they show that the channels of the great rivers are large enough to vent the floods which come from their distant sources—the wave of which is spread out and reduced on the way—and that the overflows are occasioned by the simultaneous outpouring of the smaller tributaries discharging into a channel already nearly full. They

are further important, because they teach us that to afford the most prompt relief we should seek to restrain the Ohio, which enters at the head of the delta, and the Washita and Red rivers, of which the discharge is so often disastrous to lower Louisiana. We shall hereafter see that those great navigable rivers may be controlled by simply adopting a cheap and easy method of improving their low-water navigation.

Now, we have seen that the area drained by the Mississippi is 1,226,600 square miles. Reducing this to feet, we find for the total area of the Mississippi valley, 34,195,645,440,100 square feet. We have not sufficient data for determining the average annual downfall of rain over all this immense area; but it seems probable, judging from known results, that forty inches will be extremely near to its true value. Assuming that this is the fact—and it can scarcely vary more than two or three inches from the truth—we shall have, for the total annual downfall of water on the whole surface of the Mississippi valley—a downfall which is either carried off by the drainage of the streams or by evaporation—113,985,484,800,000 cubic feet. We have not sufficient well-ascertained data to enable us to compare this, the total fall of water in the valley of the Mississippi, with the actual annual discharge of the river. But we have facts enough, obtained in the present investigation, to show that the discharge below Red river, by the Mississippi and its great natural outlet, the Atchafalaya, during sixty days of the high water in the spring of 1851, was 6,225,000,000,000 cubic feet: or at the average rate of 103,750,000,000 cubic feet per diem.

The actual drainage below Red river, during sixty days of the high water of 1851, was therefore very nearly the *eighteenth part* of the total annual downfall over the whole area of the Mississippi valley. (See note E.)

If we now divide the volume discharged during the two months of high water in 1851, in cubic feet, by the total area of the valley, in square feet, we shall find for the value of the drainage, during these sixty days, reduced to inches, $2\frac{48}{100}$ inches.

Now let us suppose, from any cause—as the tillage of the prairies, the destruction of the vegetable growth, or the better drainage of the fields—that out of the forty inches of rain which falls, *two-fifths* of an inch, or nearly *one per cent.* of the whole, should be discharged into the Mississippi in the course of these sixty days of flood, over and above the present average discharge. If this slight increase of the total discharge were distributed uniformly over the whole period of sixty days of high water, it would require that the channel of the river should be competent to give vent to an increased volume equal to 220,000 cubic feet per second. If this increased volume be retained within the channel by levees, these levees must be raised about six feet higher than the tops of the present levees.

The object of this computation is to show how sensitive is the discharge of the river to every variation, however inconsiderable, of the drainage of the country. If the evaporation be slightly reduced, or the drainage slightly hastened or increased, by the causes which are progressing, and which most obviously must produce that effect, then for every *fifth part of an inch* by which the total drainage is increased in the period of sixty days of usual high water, there must be experienced an average increase *of about three feet* in the height of the floods, unless the water can find its accustomed vent into the swamps. This result may assist the mind in forming some estimate of the consequences which are to result from the extension of

society over the yet unpeopled West, and the cultivation of the vast territory which is drained by the Missouri and its tributaries.

OF THE EXTENSION OF THE LEVEES.

It has already been stated that the recent increase of the height of floods in the lower Mississippi is a result, not of natural, but of artificial changes. It is true that in tracing the present or ancient channels of the river, we find deposites in different parts of the delta higher than the present high-water marks, and which stand as incontestable proof that the river in former ages was higher, when it left those marks, than the level of the floods which are now witnessed at the same points. These ancient floods may have resulted from an unusual downfall of water, either general or local; or they may have proceeded from an accidental diminution of evaporation, and a corresponding increase of the total drainage. But it is not always necessary to assume that the actual discharge of the river was greater than it is now, to account for the existence of those elevated spots. On the contrary, these places are limited in area, and attributable rather to local than general causes. The whole coast of the Mississippi, from the head of the delta to the gulf, exhibits indubitable evidences of former changes of its bed. Its old channels are to be found on both sides of the river, and in all parts of its course, and enables us often to trace the occurrence, or to infer the existence of some ancient *cut-off*, which must, in its day, have produced an elevation of the waters below, equal, as has been shown, to about half the descent of the stream around the bed. An ancient cut-off of fifty miles would have produced an elevation of the high-water surface, and consequent deposites below the bend, of more than six feet; and, in process of time, as the river gradually elongated its channel, and approached at that point its former condition, its banks, resulting from later deposites, would be found to be five or six feet lower than those ancient traces.

Moreover, it is not contended here that the Mississippi may not, in ancient periods, have occasionally poured larger floods into the ocean than have been witnessed within historical times. A great flood is the result of a simultaneous discharge of the great tributaries, which usually run off successively.

The high water produced by the Red and Arkansas rivers, in the ordinary course of things, has begun to subside before that of the Ohio, Cumberland and Tennessee comes down; and these, again, begin to recede before the Mississippi discharges its volume; and this, in its turn, subsides before the snows of the Rocky mountains, which swell the northern tributaries of the Missouri, are melted by the tardy sun in those high latitudes, and the water has time to flow through the three thousand miles of channel intervening between the sources of those distant streams and the head of the delta. It is a part of the natural order of events, that these great rivers shall discharge successively. But there were doubtless in former ages, as now, exceptions to this natural rule: and a meeting of the flood-waters of distant tributaries may have occurred many times in the course of the tens of thousands of years which have witnessed the formation of the delta. Such things may occur hereafter, and greater floods than have yet been seen by men may be felt along the banks of the Mississippi. But it is not these visitations of Providence which we have here to discuss and provide only those most disastrous floods which now almost annually oc-

cur, sweeping over the works of industry from year to year, devastating extensive regions, and which are referable to causes that society has created, and is still creating, and which it is therefore in the power of society to prevent, that we are here to investigate.

The floods which now carry annual distress and destruction into the lower Mississippi, it is maintained, are essentially the result of artificial causes. The water is supplied by nature, but its *height* is increased by man.

The subordinate causes to which this increase of elevation is attributable, have been sufficiently discussed. The remaining and the prominent cause, it is proposed now to consider. *This cause is the extension of the levees.*

The Mississippi has been, and is still, accustomed to find vent for its surplus waters in the vast swamps which are to be found along the valleys of Red river, the Arkansas, White river, the Yazoo and the St. Francis; and to the right and left of its proper course, almost the entire distance from Cape Girardeau to the Balize. In the original condition of the river, as it still exists above the mouth of the St. Francis, when the surface rises so as to overtop the banks ever-so-little, the water flows in through the bayous, and down the lateral slopes, and gradually fills up the immense swamps through which the channel winds, and from which it is only separated by the deposite left by preceding overflows. But each overflow leaves an additional deposite of sediment on the borders of the stream, and raises these belts of elevated soil still higher; and makes also a further deposite of lighter material in the swamps, and consequently raises the surface of the swamps in some corresponding degree. The height of the borders of the stream is, therefore, a close guide to the height of the floods to which the deposite is due.

This is now the actual condition of the upper portions of the delta, as it was that of its whole extent when the valley was first occupied by the Europeans. The early emigrants found these narrow and elevated borders extremely fertile, and capable of being made immensely productive, by shutting out the floods, which, passing in a thin sheet over the banks, filled up the swamps in the rear of their plantations, and destroyed their crops. With here and there an elevated spot, which was not ordinarily reached by the floods, the whole delta, on both shores, was frequently, if not annually, inundated. A thin column of water passed over the banks along a space of more than a thousand miles on each side of the river, and was received in the vast adjacent low grounds, which served as great reservoirs for the discharge.

In this state of things, each individual planter found it easy to protect his crop, by throwing up a frail embankment along the edge of the river in front of his estate, with wings or lateral banks running back into the swamp.

The rise of the river rarely exceeding the height of its banks more than a few inches, this slight levee was an efficient protection. But by degrees, and *pari passu* with the progress of society, these levees were extended from the lowest points of tillable land, near the gulf, up both shores of the river, until they now reach, in an almost unbroken line, beyond the mouth of the Arkansas; and are to be found at intervals as high up as Memphis. These works were originally commenced for local purposes and private protection; but, more recently, they have been planned with the intention to shut the water out from the swamps, on both sides of the river, for a great portion of seven hundred miles of its course, or, estimating both shores, for at least fourteen hundred miles of river coast.

In the progress of the levees no regard has been paid to those "bayous," or natural outlets, through which the Mississippi, in its unrestrained condition, vented, as it rose, a large portion of that surplus water which, if these openings had not existed, would have been shed over the borders of the stream, and have raised the strata of overflow still higher.

The numerous channels through which the rising floods were safely discharged into the swamps, with few exceptions, have been all stopped up by the extension of the levees across their mouths. Consequently, that portion of the flood which these openings allowed to pass into the great reservoirs of the delta has been excluded from them, and is now forced, when the levees stand firm, to flow between the artificial banks down the main channel of the river.

It will be readily perceived how this compression of that surplus water which, in the original condition of the stream, spread over a width of fifty or one hundred miles of inundated country, within a channel only half a mile in breadth, will cause the flood to rise higher and flow faster, until the additional volume discharged by the channel becomes equal to that which was before discharged by the bayous into the swamps.

The natural suggestion will, therefore, be, that to relieve the river we must restore its original condition by re-opening these closed up outlets, and again allowing the water to pass out through its natural vents.

But this is now wholly impracticable. These bayous are all types of the Mississippi itself. They originally received their supply of water altogether from the river; and in extreme floods were subject, like the river, to overflow their borders. These overflows left a deposite, of narrow breadth, parallel with the channels of the bayous, and limited in the rear by the swamps. These narrow strips of elevated soil were arable, and offered attractions to industry second only to the beautiful borders of the parent stream; and they have consequently all been occupied, subdued, and are now often highly improved. The levees which have been thrown across the mouths of these bayous, now serve to protect the plantations on their ancient borders from the inroads of the Mississippi. To open them again would lead to the certain and immediate destruction of great interests, which have grown up along the outlets; and, at the same time, would prevent the possibility of reclaiming the swamps themselves, which it has become an object of national and state legislation to redeem.

It will now be perceived why it is that the floods are constantly increasing in height on the lower Mississippi, and why it is so difficult to afford efficient protection to the country. The water which formerly escaped through these lateral vents, filling up the swamps slowly, or, as the flood increased, flowed over the borders of the great river and its tributaries, filling the reservoirs there provided still more rapidly, is now confined by artificial breastworks within the too contracted channel of the river. Consequently, as the levees are extended higher up, more water is excluded from the swamps, and the flood is therefore increased, and forced more rapidly, and in a deeper column, on the country below; thus compelling the lower planters to raise higher and make stronger the frail levees which originally sufficed for the protection of their isolated estates.

But these embankments have at length acquired such great breadth and height, in the southern parishes, that their secure maintenance has become exceedingly expensive, and their rupture the cause of great and frequent local disaster.

This is the leading cause to which the recent overflows of the Mississippi, along the coast of Louisiana, are attributable.

It will presently be seen that the evil is rapidly increasing, and destined, if not speedily arrested by the strength of the nation, to devastate one of the fairest portions of this prosperous country.

The embankments which have been raised in past years to protect the borders of the stream from inundations have been altogether the work of individual enterprise, carried on without system, under slight official control, and almost without concert. But it is not at all probable that the continuation of the system will hereafter depend on private means. Some of the parishes in upper Louisiana have already engaged in the work, and State legislation will soon be invoked there as the only power adequate to contend with the difficulty.

In the mean time the national legislature has taken the lead, and by a general grant of all the inundated lands to the States in which they lie, for the express purpose of making "the necessary levees and drains to reclaim the swamp and overflowed lands," Congress has offered inducements to the States, and through the States to individual enterprise, to commence a vast system of drainage with a view to the ultimate exclusion of the water of the Mississippi and its great tributaries from all the overflowed lands upon their borders.*

It is not for one acting for the moment as an officer of the government to criticise the past, or to dictate the future, legislation of Congress; yet it may not be inappropriate to say, that if the vast bonus granted for the purpose of excluding the water from the swamps above, and sending it down upon the States below, had been accompanied by an adequate appropriation to enable those States below to give vent to that water, or to protect their borders from the deluge which it will bring, the good which was intended by the grant would have been accompanied by less destruction than is now certain, without additional legislation, to follow the donation.

As things now are, extensive works are in progress to exclude the water from the swamps and swell the floods of the river; while no step has yet been commenced to reduce those floods, or to guard the lower coasts from their consequences.

Legislation in Missouri has already responded to the Congressional grant, by an appropriation of $50,000 to begin the work of reclamation at the head of the delta, where many hundred square miles of inundated territory may be reclaimed by art, and the land subdued, drained, and brought speedily into tillage.

The legislature of Arkansas, with equal promptness, has passed an act granting to all proprietors who may construct front levees, the right to enter the donated lands where they may choose to select them, in payment for the cost of the levees which they may rear. The details of the act it is unnecessary to repeat: but it seems to offer the most ample guarantee for the ultimate leveeing in of the whole front of that State on the Mississippi, and the borders of the Arkansas river, from the high lands below Pine Bluff to Napoleon, on one side, and to the mouth of White river on the other.

The legislature of Mississippi, prior to the passage of the act of Congress ceding the swamp lands to the States for the purpose of encouraging their reclamation, gave authority to the five northern coast counties of that

* Act of Congress approved September 28. 1850.

State to levy a tax of 10 cents per acre on all the lands in each of those counties, for the purpose of constructing front levees, and shutting out the water of the Mississippi from the great swamps extending back to the Yazoo. Under the authority of this law, the county of Bolivar alone, since the last session of the legislature, has expended about $50,000 on the levees of that county—making therewith embankments which, combined with private levees, have closed up a continuous front of about thirty miles along the river Mississippi.

The other counties extending down the coast, from the Yazoo pass to the mouth of the Yazoo river, have been making similar, but less rapid, progress. The effects of these works will be noticed hereafter. It is merely necessary here to remark that they have already been most sensibly felt, although the line is still incomplete.

This action of the counties, under the authority of the State of Mississippi, it will be observed, *preceded* the Congressional donation of the swamp lands to the States for the purpose of stimulating such efforts. We have yet to witness the effect of that grant when the legislature of Mississippi shall have convened again, and followed up the example set by the States of Missouri and Arkansas, by additional legislation based upon that grant.

Below Red river, the line of levees has been extended around Old river to the Atchafalaya, and is now in course of continuation down this, the greatest of the natural vents of the Mississippi; where all the lateral bayous, or secondary outlets, for a space of thirty miles, have been recently closed up by the proprietors, and the water always hitherto accustomed to pass through them has consequently been excluded from several hundred square miles of swamp.

Without going into the minute details of this subject, it may be said that, by the inevitable progress of causes now at work, the Mississippi water is destined ultimately to be excluded from the whole of that vast area of the delta extending from the mouth of Red river to Cape Girardeau, as it has already been nearly excluded from the area between Red river and the Gulf of Mexico.

It is a curious problem now to determine what is to be the effect of all this. While population is taking possession of the plains of Missouri and the prairies of the Mississippi, there increasing the discharge of the streams, and forcing the floods forward, by opening new drains and removing obstructions from the natural channels; States, counties, and individual proprietors, further south, are projecting and executing schemes for the reclamation of the swamps, of which the direct tendency is to cut off all the natural outlets for the surplus water, and confine the volume now spread by these outlets over vast areas of territory, within the narrow channel of the Mississippi.

By viewing together the two great causes of increasing floods—the accelerated drainage of the surface water from the cultivated plains, and the extension of the levees and systematic reclamation of the swamps along the Mississippi and its tributaries—we must perceive, without the necessity of direct calculation, the inevitable fate of lower Louisiana, unless the progress of the hastening events be by some means arrested. The levees are being extended rapidly to the head of the delta on both sides of the Mississippi. They have been raised in low places along the American bottom above Saint Louis; they are found even on the smallest tributaries of the Ohio and the Mississppi; are rapidly stretching along the entire coast of the Arkan-

sas; and have been attempted, and may yet be successfully introduced, on Red river. The drainage of the swamps is progressing with a step as steady and as fatal. Without Congressional encouragement, the ingenuity and skill of every planter has long been directed to the extension of his estate by the reclamation of the adjacent inundated lands. But now a fresh impetus has been given to these efforts in the form of a magnificent donation to invite the States to undertake the work. The bounty offered must sooner or later insure the drainage of all the swamps of Missouri, Arkansas and Mississippi. But the water that is excluded from them must sooner or later be poured down upon Louisiana. The swamps above will be redeemed: but unless adequate preventives be immediately applied, the sugar fields below will be replaced by a swamp.

Let it not be supposed that these events, though all steadily progressing, are too remote to demand present concern. Those changes which may be witnessed by persons now living, should be considered, for all the purposes of wise legislation, as things immediate. It is not assuming more than the actual progress of this country will justify, or more than is fully warranted by the history of the last thirty years, to conclude that at the close of the current century, or fifty years hence, the population within the present boundaries of this country will reach 100,000,000 of persons; and that of this number not less than fifty millions will be found within the region drained by the Mississippi and its tributaries. (See note F.)

Taking the area of this region at 1,226,600 square miles, its population in the course of half a century will average more than forty persons for each sqare mile. But a large portion of the territory lying between the western boundary of Missouri and the Rocky mountains will yield but a stinted reward to the labor of the farmer, and offer few incentives to stimulate to emigration. The richest tracts will be the most speedily and most densely peopled. The government will have been relieved of its surplus lands. The enterprising emigrant will no longer be able to purchase a farm of eighty acres of unsurpassed fertility for a hundred dollars, and must choose between the alternatives of a solitary home in the parched plains of the far west, or in the fertile but inundated lands of the delta.

It is our duty to look forward to these things. We see the work of redeeming these swamps advancing now: new levees being extended; new drains being opened: old outlets being shut off, and even the drainage pump applied, in numerous places, to keep out the water. We now see an almost unbroken line of levees stretching along the coast from New Orleans nearly to the Arkansas, on the west side of the river, and above the mouth of White river on the east; and new ones rising, from point to point, almost to the mouth of the Ohio.

It is for reflecting citizens and wise statesmen to judge what, under these circumstances, is to be the immediate effect of state legislation and the national grant on the safety of Louisiana: or what may be the condition of things when a dense population, a scarcity of land, and the exclusion of the water of overflow, shall coöperate to give value to all the inundated region which may be reclaimed by labor, and pour the waters now retained in the swamps of the upper country upon the doomed parishes below. We must look at these things and appreciate the progress of society, and its probable effects, before attempting to devise plans to retard or resist the approaching event. The expedient that will be adequate to mitigate the present suffering will have no appreciable influence on the floods that

are yet to come. That population will spread over the entire region drained by the Mississippi; and that the levees will be extended in defiance of the natural difficulties and the probabilities of crevasses, until both shores are completely guarded, must be received as certain and inevitable results. That the water which is to be excluded from these reservoirs must be accommodated by the channel, is also apparent. It is not merely the present floods, therefore, but the effect of these progressing changes in the natural order of things, which it is our province to consider and our duty to provide for.

But, in pointing out the direct consequences of the system which now prevails to an extent so alarming—of excluding the water from its ancient reservoirs, and forcing the increased burden down the proper channel of the Mississippi—it is not the design to contend against that policy. It would, indeed, be a hopeless opposition that would array itself against the countless interests, private and public, which urge these measures forward. The progress of this work is irresistible. It has become the adopted policy of Congress, as well as of individual States, and is progressing fearfully through the whole area of the delta. It is impossible to restrain the States in their career of reclamation; and no hardship or discouragement can deter or daunt those resolute pioneers who are establishing their huts upon every dry patch where they can effect a clearing for a field, or sell a few cords of wood to a steamboat.

In fact, the interest of the whole country, as well as that of the States in which these inundations occur, does demand the speedy reclamation of the swamps. But the work can only be promptly accomplished by the construction of levees; while the levees which are thus constructed for the public good, and private benefit, are most unfortunately productive of extensive local distress.

The process by which the country above is relieved, is that by which the country below is ruined.

The true difficulties of this problem will now be appreciated. We can protect Louisiana, by simple means, from all ordinary natural floods. But the great problem with which we have to cope is, to ascertain how to protect her from the deluge created by the artificial improvements which are accelerating the drainage of the prairies, and diverting the collected waters from their natural course through the low lands.

It will thus be seen that it is the pursuit of individual and public interests, through all the northern States of the Mississippi valley, that pours the excess of water down. It may possibly be considered, therefore, that it is the common duty of the States to guard the land which these improvements now endanger.

It will be useful here to reduce some of these facts to figures, that we may have a more definite idea of the consequences that will result from the exclusion of the water from a given portion of the swamps, and confining the volume so excluded to the channel of the river, when the Mississippi has already overflowed its banks and is pressing upon the levees. It has been stated that the swamp lands of the delta are supposed to cover about 40,000 square miles. But if we confine our attention at present to that portion of this area which is found above the mouth of Red river, we may estimate its length, northwardly, at four hundred miles, and its average breadth at about sixty-five miles—dimensions which give for the total area of inundated lands, north of Red river, 26,000 square miles.

If we assume that the water over the whole of this area is excluded from the swamps to a sufficient extent to reduce the depth of overflow only twelve inches, we shall have for the additional volume which, by that process, will be forced into the river, and which must therefore be carried off by the channel, $26{,}000 \times 5280^2 = 724{,}838{,}400{,}000$ cubic feet.

This additional volume must be discharged through the channel of the river in the ordinary period of high water—which, for the purpose of an example, we will here again assume to be sixty days.

The increased discharge through the channel due to this cause will then be 12,080,640,000 cubic feet per diem; and consequently 139,822 cubic feet per second.

This is about the *one-seventh* part of the actual high-water discharge of the Mississippi below Red river, and more than that portion of its total average discharge there at periods anterior to the erection of the existing levees.

But we have already seen that if only 35,000 cubic feet per second be added to the present high-water discharge of the river, its surface would be raised at or above Plaquemine, in the present condition of things, not less than twelve inches. It follows, then, that by reducing the depth of overflow throughout the swamps which are here supposed to be subject to inundation in high water, above Red river, only one foot, we shall raise the surface at high water below Red river nearly four feet for a period of sixty days.

In this calculation it has been assumed that the depth of overflow prevented by the levees averages but twelve inches, over the whole of the inundated area under consideration. But this immense area is really flooded almost annually to a much greater depth. We have no means of making any correct average on this head. In every part of the swamps which have been visited by the writer, the depth is extremely irregular—varying from a few inches to more than twenty feet.

For the purpose of obtaining better data for an approximate estimate of the average depth of overflow, a cross-section of the delta was taken from the west bank of the Mississippi opposite Memphis, to the bluffs on the west bank of the St. Francis; the point, probably, where the opposite high lands approach most closely, in the whole region from the mouth of the Ohio to the Gulf of Mexico.

The results of this survey exhibited, for the actual distance from hill to hill	35½ miles.
For the maximum depth of overflow, at high water, in the Black Fish lake	42 feet.
For the depth at high water, in the St. Francis river	52 feet.
For the average depth of the whole overflowed area	$5\frac{17}{100}$ feet.
For the area of the section of overflow	518,800 sq. feet.
For the breadth of overflow, from bluff to bluff, in a straight line	19 miles.

From these results it appears, that, at the point where the delta is probably the narrowest, and one of the points where the width of overflow is the least—if not the point where it is the least of all—the width of inundated low ground is nineteen miles, or thirty times as great as the average width of the Mississippi; and the area of overflow *two and a half times* as great as that of the average high-water section of the Mississippi.

It is probable that *five feet* is about a fair average for the depth of the

inundation, distributed over the total area north of Red river which is subject to overflow.

Assuming this to be correct, and the area, which has never been surveyed, to be correctly stated at 26,000 square miles, it follows, that, whenever the levees are made to stand firm and exclude all the water from the swamps, the quantity so excluded will be equal to five times that above obtained, or sufficient to require *an increase of discharge* through the channel, of 699,110 cubic feet per second, kept up for a period of sixty consecutive days.

It has been shown that the actual discharge of the Mississippi in extreme high water in 1851, below Red river, was 1,134,000 cubic feet per second. It follows, therefore, that to fill up the computed area of the swamps which are found above the mouth of Red river, to an average depth of five feet, will require a supply from the overflows of the river equal to 700,000 cubic feet per second for a period of sixty days, *or equal to the present total high-water discharge of the Mississippi for a period of thirty-seven days.*

In other words, if all the water which passes through the channel of the Mississippi below the mouth of Red river, when at its highest point, were discharged into the swamps above Red river, it would require a period of about thirty-seven days to fill up all those swamps to an average depth of five feet. Now, on the other hand, if that portion of the Mississippi floods which is absorbed in filling up the swamps were entirely excluded from the swamps by a system of substantial levees, and forced into the channel—where an increase of 35,000 cubic feet per second will cause an increased elevation of surface of about one foot—the 700,000 cubic feet per second so excluded would raise the surface, by the formula, about fifteen feet above the present high-water marks.*

It will be observed that, to arrive at this approximation, it has been necessary to assume the two leading elements of the problem, viz: the area of the region subject to inundation, which cannot be correctly ascertained from any data in the land offices: and the average depth of overflow, which has been estimated by mere local observation, and by inquiry of the best informed persons whom the writer has encountered in the course of his investigations.

If these facts be not underestimated, we may conclude that to levee-in the whole district, and reclaim all the inundated lands, will require levees of the usual height at the mouth of the Ohio, and gradually rising to about eighteen feet as they approach the mouth of Red river; unless, indeed, we are prepared to proceed in the work upon the theoretical hypothesis, that the river will find means to enlarge its channel, in some appreciable proportion, as the volume which it is required to carry down is increased.

We shall defer the consideration of this theory for the present, and endeavor to trace the progress of that system which is now in vogue, and the continuation of which, it has been shown, is to be regarded as the certain consequence of the increase of population and diminution of vacant land in this country.

The Mississippi river, from Cape Girardeau to Memphis, inclines towards the eastern side of its valley, and leaves the great body of its swamp lands on the west, where they are drained off by the St. Francis and a net-work of bayous, having frequent connexion with the channel.

* Allowance is rudely made, in this computation, for the increased discharge of the Atchafalaya, the increased slope, and increased breadth of surface.

Below Memphis, the river, bearing to the west, crosses its valley, and approaches the hills below the mouth of the St. Francis, leaving a great body of swamp land to the east, which there receives the waters of overflow, and drains them off through the channels of the Yazoo, the Sun-Flower and some smaller bayous.

Below the mouth of the Arkansas, the river takes a nearly southerly course, through the middle of its valley, leaving the swamps of the Yazoo, some fifty miles wide, on the east, and those of Mason, Bartholomew and Washita, of about equal width, on the west: so that between the mouth of the Arkansas and the mouth of the Yazoo, the swamp lands of the Mississippi—the great reservoir of its waters of overflow—spread over a width of about one hundred miles.

Below the mouth of the Yazoo the principal portion of the swamps is on the west, where they have a natural drainage through various bayous into the Washita and Black and Red rivers.

Now, the flood that comes from the Missouri and upper Mississippi, first begins to overflow the banks of the river above the mouth of the Ohio, where a large volume of water flows through the pass between Cape Girardeau and the insulated high lands south of that place, and, spreading over a considerable area of swamp, discharges itself into the St. Francis. Below this insulated mass the thin column of overflow is received into the lakes, bayous and swamps of the southeastern counties of Missouri, lying between the St. Francis and the Mississippi; while the main channel of the river conveys the swelling wave further forward. The water continuing to rise in the river above, the column of overflow becomes deeper, and gradually extends along the whole front of Arkansas, above the mouth of the St. Francis, sweeping over all the lower portions of the western coast, and gradually filling up the great basin of swamps extending nearly from White river to the Mississippi, and supposed to cover an area of 5,000 square miles.

Assuming that this area is an approximation to the truth, and that these swamps are overflowed at high water an average depth of 5 feet, this reservoir alone must draw off, and hold in reserve, while the flood is passing through the channel, about 696,960,000,000 cubic feet.

But we have ascertained approximately, by actual measurement made when the water was within a few inches of its extreme height, that the whole discharge of the Mississippi river, above the mouth of the Ohio, during the flood of June, 1851, was 1,025,000 cubic feet per second, or 88,560,000,000 cubic feet per diem.

Consequently, the swamps on the western side, from Cape Girardeau to the mouth of the St. Francis, must draw off and hold back a volume of water, during a great flood, equal to the total discharge of the Mississippi itself, at Cape Girardeau, for a period of very nearly *eight days*.

The levee which the State of Missouri is about to build across the wide inlet below Cape Girardeau, will exclude the water of the Mississippi from a part of these swamps, and destroy them, as reservoirs, for that portion of the floods which they now absorb through this pass. But the further policy of the State of Missouri, as well as that of Arkansas, for the drainage of the residue of the inundated district above the mouth of the St. Francis, has not yet been fully developed. It is, however, certain that neither of these States can accomplish their object, or make the lands donated to them by the act of Congress extensively available, with their own resources, without constructing a line of levees along the whole front on the Mississippi,

and excluding the water of overflow entirely. It may therefore be assumed that they will be compelled ultimately to resolve on this course, if they have not already decided on its adoption.

We are not prepared to estimate what must be precisely the increased elevation of surface, to enable the river to discharge the additional volume which is now poured into any portion of the swamps, in a given period of time. But if we estimate the mass needed to raise the river twelve inches to be the same at the mouth of the St. Francis as it has been computed to be below Red river—from which it cannot very materially differ—we shall have for the increased daily discharge which will be occasioned by an increased elevation of four feet, 86,100 seconds × 35,000 cubic feet × 4 = 12,096,000,000 cubic feet: from which we will deduce for the time required to vent through the channel of the river the volume which now passes, or is here supposed to pass, into the swamps above the mouth of the St. Francis, without increasing the floods more than four feet,

$$\frac{696,960,000,000}{12,096,000,000} = 58 \text{ days.}$$

We may conclude from this course of calculation that, by constructing levees four feet higher than would be necessary to protect the borders of the Mississippi from overflow, in the present condition of things, at the mouth of the St. Francis, and gradually diminishing their height to that actually required by the present flood, as we proceed upwards towards Cape Girardeau, we shall be able to exclude the Mississippi water, and drain all the swamps on the west side of the river, north of Helena. In this computation, however, it is assumed that the water is confined to the channel by levees on both sides of the river. If that be neglected, then the Kentucky and Tennessee low grounds will be inundated, back to the hills on the east, and levees of much more moderate height will suffice to protect the coasts of Missouri and Arkansas.

Now let us proceed to a lower point along the Mississippi, and ascertain the probable condition of things there. The water which will be shut out of the great basin now drained by the St. Francis, will be hurried down upon the State of Mississippi—first upon the coast which bounds the swamps of the Yazoo: and upon the opposite coast of Arkansas, from the mouth of the St. Francis to the mouth of the Arkansas river. But here again, as has been stated, works are in progress to ward off the waters and reclaim the inundated low lands. The northern counties on the west border of Mississippi have been for the last year, and are still, at work, raising embankments along their respective fronts to keep the river out. Extensive private levees on the opposite shore have been commenced below Helena, and the State of Arkansas is just embarking in a systematic scheme for the reclamation of her inundated territory. There is, in fact, ground enough to justify the assumption that an unbroken line of levees will be made, or attempted to be made, in the course of a very brief period, on both sides of the Mississippi river, from the mouth of the St. Francis down to the mouth of the Arkansas.

If these levees be made competent to resist the weight of water, their effect, combined with the present levees on the Mississippi side below White river, will be to drain 5,000 to 6,000 square miles of swamps above the mouth of the Yazoo, and 2,000 or 3,000 square miles more, on the Arkansas side, between Helena and Napoleon.

All the water which will thus be excluded from an area here assumed to

be 8,000 square miles—now supplied by the overflow conveyed through the Yazoo pass and numerous bayous leading into the Sun-Flower and Yazoo rivers—together with that excluded volume which will be sent down from Missouri and the upper portions of Arkansas, will be hurried on to the mouth of the Arkansas river, there to join the increased flood which the State levees now in course of preparation on that river, are about to send forward to the same point.

It must be concluded, therefore, that the region embracing the mouth of the Arkansas, White river, and Lake Bolivar, is shortly to become the scene of extensive overflows, unless protected by the weakness of the works which are in preparation above.

It is important to take note of the condition of things here, for we may consider the mouth of the Arkansas river as in some degree the commencement of serious dangers, as it is in a great degree the commencement of most valuable improvements, which are threatened with destruction from the anticipated accumulations of water at this point. It is a point which will be found important in another aspect, viz: as requiring a special examination with a view to ascertain whether it may not be practicable and advisable to leave a vent somewhere in this region, through the contemplated levees, for the purpose of forming a great outlet to convey a portion of this artificial flood into Red river, and thence, by a corresponding outlet through the Atchafalaya, into the Gulf of Mexico.

The effect of all these contemplated works, from Missouri down, is obviously to concentrate the present waters of overflow, and hurry them on to the mouth of the Arkansas. But the plans which have been resolved on, and in a considerable degree executed, by the local authorities, leave no vent for them here. On the contrary, the counties of Mississippi from Lake Bolivar to the mouth of the Yazoo, as has been shown, have already nearly perfected, according to their own views of what is necessary, a line of embankment along their entire coast; while it has been seen that the commissioners of Arkansas are preparing to carry on the line upon the Arkansas side, until it meets that of Louisiana at the boundary of the two States.

If these immense lines of earth work could really be depended on to control the Mississippi, and exclude the water from the swamps, we might perhaps be able to approximate roughly to the increased height of the floods which will be produced in the river from the mouth of the Arkansas to the mouth of the Yazoo.

But a most important feature in the elements of this problem, is the fact, that none of the States or counties have yet planned their levees with any reference to the increase of the floods which their own levees, or those in course of construction above or below them, will produce. In all cases they seem to be guided by the lines which mark the level of former high water.

This fact leads us to the discussion of two considerations that merit attention, in estimating the effect of completing the levees now in course of construction, which hold out a prospect of some relief, and indeed, if properly improved, certain protection for a season, to the country below.

The most important of these considerations is the great difficulty that will be experienced in the first attempts to close up the works now in progress, so as to make the embankments continuous along the whole coast. Up to the present time this difficulty has not been so seriously felt, because

the water has found vent through unleveed districts above, and crevasses below. But each mile of levees that is reared and made secure will increase the labor of constructing new ones, and the cost of maintaining the old ones. Those that are now in course of construction, like all those that have been built in past years, are made with a view to resist the pressure of that depth of water which is anticipated on the basis of past experience. But past experience does not include the new elements—the effects which the levees themselves produce on the height of the floods—and the first levees are therefore made too feeble, and will give way and be thrown back, and rebuilt, perhaps many times,—as the old ones have been,—each successive levee rising higher and being made stronger than that which preceded it.

The water will thus be permitted to diffuse its force by spreading again over the swamps of the Tensas, the Yazoo, and the St. Francis.

This is a practical and certain guarantee for temporary reprieve to lower Louisiana. But it is, nevertheless, not one on which prudent men may permanently rely. Experience is acquired quickly in this country. The property which will be invested in these new levees, however slightly they may be constructed, and the lands which will be reclaimed by them, however difficult to protect, will be additional pledges that the embankments will ultimately be made to resist the floods. Consequently, this difficulty of maintaining the levees above, though real, can only be regarded as in some degree an assurance that the whole effect of the works now in progress will not be immediately felt. But this is no substantial ground of hope for the future. The waters must ultimately be excluded from all the swamps, and pressed down upon Louisiana.

This State must, therefore, it is repeated, prepare either to give them additional vent, or to resist them, or consent to be deluged.

Moreover, it is to be recollected that while these frail works will fail of their present object, and be burst in numerous places by the floods which they will be the means of producing, they will, nevertheless, generally stand firm until the water rises nearly to their summit, and when they give way, only fail in places of limited extent: so that, although the swamps will not at first be effectually drained, the water will be kept out of them, even by these inadequate levees, for a longer period; and the floods from the upper streams—which, by the wise ordination of Providence, usually send forward their spring waters after those of the lower tributaries have subsided—will be hastened on to meet those which come from the rivers below.

In short, the embankments which are now in course of construction in Arkansas and Mississippi will not be found sufficient to resist the higher waters which they will ultimately produce; but they will serve, nevertheless, to increase materially the height of the floods below, to hurry the wave forward, and add disastrously to the present distress of the people of Louisiana.

This State may look, therefore, for a temporary and partial reprieve due to the insufficiency of the works which are in preparation to inundate her coast. And it is to be hoped that this precious time will be given to prompt and enlightened efforts to prepare for the approaching trouble; and that it will not then be supposed, if it should chance for a year or two that the flood of Red river passes off harmlessly before that of the Arkansas comes down, or that both of these have discharged before the Ohio pours

out its volume—because there may happen for one or two seasons to be no coincidence of the freshets of the great tributaries—that the views here presented are mere speculations, or that the Mississippi is too great to be influenced by the works of men. They are, unfortunately, no speculations; and, if a year of low water should be permitted to intervene, it will be the part of wisdom for Louisiana to profit by the delay, and push forward her defensive works.

The other argument which has been urged as a ground of hope, is the probability that, as the depth and mass of water forced through the channel are increased, the size of the channel itself will be proportionally enlarged.

It is certain that this is one of the laws to which all streams flowing over alluvial beds are obedient; that, *cæteris paribus*, their abrasive force increases with the volume of water transported, and that the channel is enlarged as the abrasive power is augmented. But, before this can be made a ground of encouragement, it is to be observed that the scouring force of the river cannot be increased until *after* the surface has been raised; and, therefore, after the damage has been done.

This law is only available as an argument to prove that, though the people of to-day may be deluged, their descendants, if they continue the contest, and set back, rebuild, and strengthen their levees, will ultimately obtain relief. But *when* that relief will come; *when* the bottom will be washed out deep enough, and the banks will have caved in far enough, to accommodate the increased volume, it is beyond the prescience of science, or the light of experience, to foreshow. Indeed, all our observations upon the Mississippi go to establish the presumption that, although the river, while depositing its bed, and forming its channel in the material which it transports, readily adapts its section to the volume which it bears; yet, after that work is accomplished, its bed is formed and its dimensions are determined, it is extremely slow in its efforts to readjust its arrangements. The cut-off at Raccourci, made three years ago, is not yet washed out, by one-third, to the usual dimensions of the channel; though, by reason of the contraction of the water-way, the velocity of the current at that point is greatly accelerated. The Horse-shoe cut-off was made many years ago; and up to this time the river at that place—notwithstanding the speed of the water is very much increased there in all stages of the river—presents a water-way of about twenty per cent. less than the average area of the river's section.

In fact, this principle of compensation, so often alluded to by scientific writers, offers no substantial ground of hope. It has value, perhaps, as a geological truth, but it affords no solid comfort to present society. When we increase the volume discharged by the river, the channel will no doubt undergo a gradual enlargement; but more than a thousand miles of material must be excavated and transported—re-deposited, re-excavated, and again transported many hundred times: and we have no reason to doubt that hundreds, and perhaps thousands of years will be required to do the work, and restore the ancient condition of things.

But it is contended by persons of intelligence and observation, that the construction of levees in the upper parts of the river cannot increase the floods essentially below; for the reason that the channel below is larger than that above, and can therefore vent between levees all the water that can be brought down between any new levees which may be built above.

The assumption on which this hope is founded is erroneous in fact. The Mississippi river may be, and is, generally larger near Red river than it is in the neighborhood of Memphis. Yet there are portions in its upper division, towards the Ohio, which are much larger than other portions below the Yazoo. And it may be added here, as a curious fact, in itself a perfect refutation of this view, on which hope has been promised, and a truth pregnant with other important consequences, that *the Mississippi, when in flood, discharges more water immediately below the mouth of the Ohio than it does at any point in the neighborhood of Red river.*

The maximum discharge of the channel below the mouth of Red river at the top of the flood of April, 1851, was----------	1,134,500 c. feet per sec.
The discharge below the mouth of the Ohio June 10, 1850, when the water was there *nine feet below the top of the flood of* 1849. was------	1,223,000 " " " "
At the same point, at the top of the flood of 1849, by estimation, the discharge was not less than	1,700,000 " " " "

Apart from the inaccuracy of the facts, and the insufficiency of the elements upon which this view is based, it is at best a specious argument, and holds out but a fallacious hope.

It in reality assumes that the water which is now discharged into the swamps above, passes through those swamps and re-appears at their outlets, and aids in swelling the flood in the river below. But this is all at war with the facts. The flood in the river travels faster than the flood in the swamps; and the highest rise at the mouth of the St. Francis is not produced by the water of overflow which entered those swamps above and is drained off by the St. Francis: nor that at the mouth of the Yazoo by the water which is drawn through the swamps of the Yazoo; nor that at the mouth of Red river by that which is discharged by the Cocodrie and the Tensas. The floods of the Mississippi are produced by water which does not go into the swamps at all, but which descends through the main channel of the river; aided by the discharge received from the tributaries on the way. The height of the flood at any point depends on the volume that is brought down by the river and its tributaries, and not by the discharge from the swamps. But, *after the river has attained its height*, the supply is kept up, and the duration of the flood prolonged, by the subsequent discharge from the swamps.

If, therefore, the levees be so raised at the mouth of the Arkansas, and the water so far excluded from the low grounds, as to produce an increase of the height of the floods there—say three feet—the height of the levees near the mouth of Red river must also be increased about three feet; the precise amount depending on local circumstances.

In fact, the effect of extending the levees, which is here contended for, was clearly demonstrated by the spring flood of 1851. As has been stated, the coast counties of Mississippi, during the previous autumn, had extended and closed up their detached levees over a continuous line of fifty or sixty miles,—partly above and partly below the mouth of the Arkansas. But the levees were not materially extended on the opposite or Arkansas side. Consequently the water was only excluded from the swamps of the Yazoo for this distance, and still had vent into those of Arkansas.

Now, the flood of 1851 was not a great flood. About fifty miles above

the mouth of the Arkansas it was ten inches below the flood of 1850 in the Mississippi; and an equal distance beyond the back water from the Mississippi, the Arkansas itself, in 1851, was nearly *three feet lower* than it was in 1850.

The height of the flood of April, 1851, at the mouth of the Arkansas, ought, therefore, to have been expected to be at least one foot lower than it was in 1850. But in consequence of the levees constructed above, on the Mississippi side, by Bolivar county, the water was excluded from the swamps on that side immediately above the mouth of the Arkansas; and we accordingly find that the flood of 1851, at and below Napoleon, was within four inches as high as that of 1850. Here was a visible effect of eight inches due to the new levees above. (See fig. 8.)

But the levees in Mississippi, as we have seen, between the dates of these two floods, were perfected many miles further down. Following the coast about 80 miles, to the lower end of Bunche's bend, we find that the flood of 1851 was 2½ inches *higher* than that of 1850, instead of being, as it ought to have been, according to the volume sent down, about 12 inches lower. Here, then, was an effect of 14½ inches apparently due to the new levees raised in Bolivar and Washington counties in the summer and fall of 1850.

Proceeding some 10 miles lower, we find the flood of 1851 about *eight inches higher* than that of 1850, instead of being 12 inches lower; showing an effect of 20 inches near Lake Providence, produced by the new levees formed above that place during the preceding season.

This effect was, however, of very brief duration. The levees were not prepared for this pressure, and gave way. A great crevasse occurred at Point Lookout, on the Louisiana side, below Providence, and numerous breaches had taken place on the Mississippi side, through which the water poured into the swamps of the Tensas and the Yazoo; and the flood below was accordingly reduced, and the levees saved.

Such results will be witnessed again and again. The country along the coast below will be saved by the feebleness of the works above. But each time the embankments break, they will be rebuilt and made higher and stronger; and each victory gained over the waters in the north, will consequently add to the distress of the south.

It is not to be supposed that Louisiana can afford to raise her levees as fast as the new levees above will make such a course necessary for her safety. The levees near the head of the delta will be but five or six feet high, and be capable of sustaining a pressure of three or four feet of water. But if we add a pressure of three or four feet to the height of a flood threatening an old levee, we must sacrifice the original bank altogether, and build a new one three or four feet higher. To resist a flood *increased four feet* in Louisiana, will require an expenditure more than three times as great as to build a levee adequate to resist a pressure of four feet in Missouri, besides involving the sacrifice of the old work. To maintain the new levee, apart from the increased risk, involves an outlay equally disproportionate.

It will be perceived that, in the view of the writer, the levees are destined to be extended the whole length of the delta, wherever there is inundated land to reclaim, of which the value, when redeemed, will justify the cost; and also, that as the water is excluded from the swamps, and confined between the levees, it must continue to rise until it obtains depth and

velocity sufficient for its discharge through the channel, or until the levees break; that, practically, society can hope for no relief from the unassisted enlargement of the channel, or from any thing but immediate efforts to give lateral vent to the water, or to restrain it by appropriate works.

So long as levees are raised and lengthened above, we must therefore expect the country below to be assailed by increasing floods.

In this state of affairs it is difficult to conceive of a case more deserving of the generous sympathy of the country, than that of the people of Louisiana. It should never be forgotten that it is precisely those efforts which are resulting in prosperity and gain to their northern neighbors, that are pouring ruin upon them. It is not the place of the writer to point out what measure of protection justice demands for the injury inflicted by these works, or to say what, if the States of this Union were to be regarded in their reciprocal relations as individuals, would be the legal claims for redress of the one that is injured by a diversion of the waters from their natural course, upon the parties who, in the pursuit of their own interest, cause the injury. It is his study simply to point out the facts, and the physical remedies which may be applied, leaving the question upon whom the weight shall fall to repair the evil, to the wisdom of Congress.

PART III.

OF THE MEANS OF PREVENTING INUNDATIONS.

To persons unacquainted with the peculiar formation of the delta of the Mississippi, and especially to those who are unused to the measurement and contemplation of forces, the question of *absolute practicability* will naturally occur, when it is proposed to control and regulate the flow of a vast river, which is known to drain seven hundred and eighty-five millions of acres, and discharge through its channel the floods produced by the melted snows of the Rocky mountains and those of the Alleghany, together with the surplus water of hundreds of tributaries in the intervening valleys. It will be advisable, therefore, to glance at this question first, and attempt to compare the weight of water discharged by the river, with those ordinary powers which are directed by men.

If our object were only to relieve the country from the floods which are now felt, this problem, in the opinion of the writer, would involve no serious difficulty. Outlets could be made in lower Louisiana, and the levees could be strengthened along the coast, in the upper part of the State, to an extent sufficient to afford the most ample protection. But we have seen that each year is destined to add to the power of the floods; that every mile of levee which is built increases the height and speed of the water; and that each new farm that is opened on the prairies, increases the volume that is poured into the streams. In short, it has been shown that the great difficulty of protecting the delta from overflow is produced by the extension of the artificial embankments along the borders of the stream, and the cultivation of the prairies of the upper States.

The real problem, therefore, is to decide how to guard against these artificial floods, which are annually increasing, by some counteracting artificial expedients.

It is not unreasonable to assume that if it be in the power of individuals so to control the waters as to add to the height and violence of the river, it will be equally within the power of this Government to reduce its force and moderate its velocity. Indeed it might be shown that force enough has been assembled in arms to protect the nations of Europe from the ambition of a single mind, to be able, if applied to such an object, to pump the Mississippi dry; that the standing armies of Europe are at this day sufficient, without the aid of science, and almost without the use of machinery, to *bail out* the floods of this river, and, pouring them into the sea through artificial conduits, maintain the water in the channel at any level that might be prescribed.

It is known, from measurements recorded in this paper, that the total discharge of the Mississippi and its natural outlets in extreme high water, is about 1,270,000 cubic feet per second; and that to raise the surface twelve inches, when at its extreme high-water mark, will require, in the average, an addition to its usual supply of about 35,000 cubic feet per second.

Now, the power of a horse is conventionally estimated to be equivalent to the raising of one cubic foot of water to a height of nine feet in each second of time; or, reciprocally, to lifting nine cubic feet of water to a height of one foot in each second.

The Mississippi and its tributaries are now navigated by about fifteen hundred steamboats, of which the average power may be safely estimated at about four hundred horses. Consequently, the total horse-power engaged in transporting the products of industry through this valley—those products which it is the object of this investigation to protect from the effect of floods—is about equal to six hundred thousand horses. From which it follows, that the steam power actually engaged in navigating the Mississippi and its tributary waters is adequate to the lifting of *all the water discharged by the river and its outlets*, at the moment when their discharge is greatest, as fast as it comes down, to a height of about

$$\frac{600000 \times 9}{1270000} = 4\tfrac{2}{10} \text{ feet.}$$

But, to reduce the surface of the Mississippi and its outlets below the mouth of Red river two feet, will only involve the discharge of about 75,000 cubic feet per second.

To lift 75,000 cubic feet per second to a height of two feet, will require a force of

$$\frac{75000 \times 2}{9} = 16{,}666 \text{ horses;}$$

which is equivalent to the power of the engines of about forty-two steamboats of the average size of those engaged in the navigation of the western rivers.

It is useful thus to compare the power of the river with those forces which men are accustomed to employ, for the purpose of showing that the quantities to be dealt with in controlling the Mississippi are not, as might be hastily assumed, too great for the means which it is in the power of this country to apply. Beyond this, such computations are of no practical value. They will serve only to show that, in order actually *to lift* the surplus water out of the channel of the Mississippi, and convey it through independent outlets to the sea, would not be too great an undertaking for

this age; or, perhaps, greater than would be justified by the value of the vast area of overflowed lands which it is the object and interest of the whole country to reclaim.

It is, in fact, within the ability of society to restrain these floods by mere muscular strength—by steam-power—or by a dead lift, and without the aid of any of those resources which are supplied by art and experience. But, while it is useful, in contemplating subjects so large to bring into comparison things which are unknown, with others that we are capable, from daily experience, of readily appreciating, it is not necessary to pursue such a line of inquiry. We shall presently find that great volumes of the Mississippi floods may be discharged directly into the sea, by merely removing a portion of the artificial embankments which now confine it to the river; or, that the floods may be controlled by retaining a portion of the water in the valleys above, until it may pass tranquilly to the ocean without injury to the country below. While we have the means of causing the river to regulate itself—to apply its own power to producing its own discharge—it would be unwise and unnecessary to seek extravagant modes of accomplishing our purpose.

It is proposed now to discuss these simple processes.

OF THE PLAN OF OUTLETS.

The mode almost universally recommended for obtaining relief from the overflows of the Mississippi, is that of creating artificial outlets to draw the surplus water, from the river and discharge it, through new channels, into the Gulf of Mexico. The earliest suggestion of this plan which has been seen by the writer, is to be found in Darby's account of Louisiana, published in 1816, where its essential features, as they are at this day presented, are fully chalked out.

But, it is very certain that the preference given to this method is attributable to the tempting facility of execution which it offers for the relief of the estates below Red river, and along the immediate borders of the Mississippi. The least knowledge of the physical formation of the lower portions of the delta, is sufficient to satisfy every mind that this plan is perfectly feasible, and may be executed there with great promptness and efficiency. Indeed, along this portion of the river, the pressing difficulty is not to give vent to the surplus water, or send it to the sea by artificial channels: the precise difficulty is to prevent the flood from bursting through its artificial barriers and venting itself.

The Mississippi, as has been already shown, is actually elevated during high water, from fifteen to twenty-five feet above the soil a few miles distant on either side of its course; and is only prevented from breaking out and deluging the interior by the artificial embankments which have been reared along its coasts. This embankment usually gives way during high floods, in some weak points; and the *crevasses* thus formed act as vents to the over-burdened channel. The proposition to create artificial outlets is here intended to supersede these spontaneous breaches; and for that purpose, and to that extent, they will be recommended in this paper for the protection of lower Louisiana.

But this plan, simple, easy of execution, and certain as it is when applied to a limited extent on the lower portions of the river, is obnoxious to some

well-founded objections, and has encountered much opposition from unfounded apprehensions.

First, among the legitimate objections is the difficulty of giving vent to the surplus water which now comes down, and *a fortiori* to that which, in the view of the writer, is destined hereafter to come, in sufficient volume to protect the coast without deluging other portions of the adjacent country, already suffering from the very excess that now prevails on the Mississippi itself. This is a solid objection to a plan in other respects highly useful and applicable, within reasonable limits. But it involves the necessity of sacrificing one interest for the protection of another which is assumed to be greater—an alternative which cannot fail to render it odious to all whose interests are threatened.

Another objection to this plan, which is also founded in reason, is the certainty that great deposites will be left in the lakes into which the waters withdrawn from the Mississippi will be discharged before they can reach the gulf; deposites which will not only impair the navigation of these lakes, but ultimately convert them into swamps, like those which it has become one of the great objects of the whole population of the delta to reclaim and bring under cultivation.

Then, there stands in the way the apprehensions seriously entertained, and forcibly expressed, by engineers of great intelligence and respectability, that the abstraction of a portion of the water by lateral channels will cause a diminution of the velocity of the current, and a consequent filling up and contraction of the present channel of the Mississippi below the points at which the water is withdrawn. Whence it is concluded that, as the channel of the river will become smaller than it now is below the new outlet, and the speed of the current will be diminished there, the discharge of that channel must become less in proportion as the outlet is greater; and that, consequently, there will be really in the end no appreciable reduction of the height of the floods effected.

Finally, there is the opinion, thrown out and vigorously maintained by others, that these new outlets having shorter routes and a greater descent than the river itself, they will be rapidly abraded by the escaping water, and ultimately so much enlarged as to become the main outlets or true channels of the river, and thus lead to the eventual destruction of the present channel and its invaluable navigation, and consequently involve the ultimate decay of the city of New Orleans.

As the plan of artificial vents, or *high-water wastes*, is here recommended as a prompt, efficient and available means of relief for the coast below Red river, it will be proper to discuss these several objections at the outset.

EFFECT OF OUTLETS ON THE AREA OF THE CHANNEL.

The writer does not participate in the apprehension of those who look forward to a diminution of the present width, depth or velocity of the Mississippi, from deposites consequent on the discharge of its waters of overflow through independent outlets. This apprehension is not at all shared, though the principle which looks for the accommodation of the size of a river's channel to the volume of water which passes through it, along a given slope, is fully admitted.

Certainly there are, in a channel formed in an alluvial soil, reciprocal relations between the depth, breadth, slope, velocity and discharge. In other

words, these quantities are each functions of the others. But we are not thence hastily to conclude that a certain portion of the high-water discharge of the stream may not be withdrawn without producing a proportional contraction or diminution of the breadth or depth of the channel. There are several impediments to this conclusion.

To excavate a channel through a soil of given texture, and to keep the same channel open when so excavated, are two very distinct things, implying very different applications of force.

To wash out a channel, requires a velocity and power not merely sufficient to carry off the material, but to overcome its cohesion and inertia, and transport it in addition.

We find, consequently, that it is no easy thing, even with a great fall and a great volume, to open a new channel by the mere action of the running water of the Mississippi. The first attempts to make the cut-off at Raccourci, where the fall was at the rate of six feet per mile,* were unsuccessful, although a considerable volume of water was let through an artificial trench leading from the river above to the river below the bend.

Various other attempts to create cut-offs across the bends in the upper portions of the river have likewise been unsuccessful, although sometimes aided by a descent across the bend of seven or eight feet per mile.

The Atchafalaya and the Plaquemine have probably been open for ages—certainly from periods far beyond the reach of history or tradition—the first having a fall more than twice as great, and the other a fall *ten times as great*, as the Mississippi itself; and yet, unaided by art, they have been found unequal to the task of increasing the depths of their channels, or enlarging their respective water-ways. On the contrary, the Atchafalaya, in the view of the writer, seems to have been contracting its original width for a great many years.

The crevasse at Bonnet Carré discharged into Lake Pontchartrain about the one-tenth part of the high-water burden of the Mississippi, for many consecutive days, during the great flood of 1850, when the water of overflow rushed down a plane descending about fifteen feet in 4½ miles; and yet the velocity and force of the torrent were not sufficient to tear up the natural soil to any considerable extent. No channel was excavated. The furrows left by the plough and the roots of the crop remained on the field where it had been swept by the water, after the flood had subsided.

Without multiplying examples, it is admissible to say that the power required to excavate a new channel, or to enlarge an old one, is much greater than is needed to maintain such a channel after it is once opened.

It does not follow, therefore, that the capacity of the Mississippi will be diminished by high-water outlets, even if a part of the water which originally formed the channel should be withdrawn, for the reason that it requires more force to create, than is required to maintain the channel after its formation.

But there is another reason for the practical conclusion, that extensive outlets may be formed without a shadow of fear for the preservation of the channel below. The Mississippi and its natural outlets are now greatly overburdened in times of high water, and are unable to vent the volume which is poured into them by the distant tributaries as fast as it is brought down. This *excess* of water finds new outlets by overflowing the banks, or through crevasses in the artificial levees. Outlets, then, acting only as *high-water*

* It was just 4½ feet in three-fourths of a mile.

vents, through which this surplus may be let off, cannot possibly diminish the actual area of the river's section below; for such outlets will discharge water which does not pass through the channel at all. The water which injures the country is not that which descends between the natural banks—or even that larger quantity which now descends between the levees of the Mississippi—but is precisely that which, after the levees have given way, leaves the channel and spreads over the cultivated fields. We may surely discharge this portion through artificial openings leading to the sea, without effecting the area of the channel below: for it does not now, and never did, flow through the channel, and has, therefore, no influence whatever on its condition.

Again: it has been seen that the height of the floods of the lower Mississippi is annually increasing, in consequence of the extension of the levees above. In opening outlets below Red river sufficient to give passage to this *increased* supply, as it comes, we cannot possibly impair the efficiency of the present channel, for this increased discharge has had no part in the creation or maintenance of the present channel.

To the extent, then, in the first place, of discharging the waters of overflow, or the crevasse water: and to the further extent of providing for the increased discharge which the new levees will occasion, we may employ artificial outlets without the least apprehension that the present area of the river will be diminished by success. And still beyond this we may carry that expedient, until we approach the unknown limit which represents the difference between the volume needed to create, and that needed to maintain the channel.

These limits allow us margin to open outlets far beyond our means of producing, with proper regard to the safety of those upon whom the surplus is to be turned.

A word may be added in allusion to the fear often expressed, that the new outlets which it is proposed to open at points where the route which the waters will follow to the sea will be shortened, will ultimately become so enlarged as to absorb the Mississippi itself, and thus leave the city of New Orleans on some secondary bayou.

The reply to this apprehension is the fact already stated, that the water passing through such vents is never known to cut out or deepen their channels without assistance. The bayous which still lead from the Mississippi into the adjoining lakes and swamps, have been in activity during thousands of years, and do not seem to have gained the least on the Mississippi; while the whole delta shows evidence of ancient outlets which have been filled up by deposites, and no longer act in relieving the discharge of the river.

The Bayou Plaquemine descends from its source to the Indian village, eight and a half miles, at an average rate of 2¼ feet per mile, and in one place no less than three feet in a single mile, having a depth of more than thirty feet, and a current which can only be stemmed by a powerful steamer; and yet it does not appear to gain upon the soil or to enlarge its area. Indeed, the writer is not in possession of any fact which goes to show that any outlet can be made from the Mississippi above New Orleans, which, left to itself, will become larger and ultimately excavate a new channel into the gulf. If we could calculate with confidence on such a result, the problem of protecting the country below Red river would be relieved of all its difficulties at once, for we might then open an outlet into Lake Borgne, and, turning the

Mississippi into that arm of the gulf, transfer its embouchure to the deep water south of Ship island, and reduce its high-water surface some six feet at New Orleans. But, unfortunately, the water cannot open the way without assistance, and the new channel will not be produced without other aid.

The danger anticipated does not, therefore, exist. The channel will only be enlarged as we seek to enlarge it: and it will of course be the duty and the care of the engineer to keep it always under control. For those, however, who apprehend that the tendency of things might be different, it may be said that these outlets can be completely controlled; that nothing is easier than to limit their discharge to the precise amount which we wish to pass through them. To *increase* their draught involves some difficulty. To stop them up entirely, requires no skill and but little labor.

The outlets which it is proposed to open, like the ancient natural outlets of the river, will only act in times of high water: and as the bottom of their channels will be eighty or ninety feet higher than the bottom of the Mississippi, and at the same time higher than the surface of the sea, to assume that they will be capable of cutting a trench to the gulf sixty or eighty miles distant, competent to drain the Mississippi, we must assume a power adequate to the excavation and transportation of that mass of material, or a prism eighty feet deep, three thousand feet wide, and sixty or eighty miles long.

There is nothing known in the past history of the Mississippi, and nothing that can be inferred from its present habits, to warrant such an assumption. The cut-offs, whether natural or artificial, to which so many former changes of the river's bed are referable, are not in opposition to this conclusion. To produce a cut-off requires the excavation of a trench through a narrow neck of land dividing one channel one hundred and twenty feet deep, from another of equal depth, where the water is precipitated rapidly through the material to be removed, and conveys it directly into the gorge of the Mississippi itself, possessing a power always in activity to bear it away.

There is here the power to loosen the material, the space to discharge it into, and the power then to remove it as it comes. In the case of the new outlet, the material to be removed must be conveyed many miles through lakes and swamps, where the current is resisted by stagnant water, where the power of the river is exhausted: and must finally be deposited in a shallow arm of the sea, which it has not the force to repel.

These objections to the use of outlets to a limited extent, are not tenable. It is therefore proposed to resort to high-water vents, so far as is necessary to obtain prompt though limited relief from pressing distress and impending calamity; but not to rely on this expedient exclusively, or even to look to it for full relief or permanent security.

The object of this examination is not considered to be merely the protection of the country below Red river from the difficulties against which the population there is now struggling, but to embrace the whole area of the delta, and to do the work by some plan that will not be incompatible with the intention of Congress, as it is manifested in recent legislation, to reclaim all the lands in that vast area which are subject to inundation. These great purposes will be aided, but not accomplished, by outlets: which, therefore, are now only recommended for local relief and limited application.

OUTLET BELOW NEW ORLEANS.

About eleven miles below the city of New Orleans, and one hundred above its mouth, the Mississippi approaches within five miles of the Gulf of Mexico. The ground between the river and the gulf, here known as Lake Borgne, is a plane sloping from the river back to the sea. The first three thousand feet from the river is cleared and highly cultivated land; but the residue of the distance is swamp, always wet, and sometimes completely overflowed by the high water of the gulf.

When the Mississippi is in flood, its surface stands six feet above the level of the adjacent soil, and the water is prevented from inundating the sugar fields by artificial levees about six feet high.

At the distance of half a mile back from the levee, the surface of the ground is 9½ feet below the high-water surface of the river. At the distance of a mile, it is 10½ feet, and so continues, almost a perfect level, from that point back to the borders of the lake, where the surface of the swamp or prairie is 10¼ feet below the high water of the Mississippi, as it stood in April, 1851.

The level of the gulf at the time of the survey was just eleven feet below high water in the Mississippi; but marks were exhibited which showed that in 1848 the lake had risen to within seven feet of high water in the Mississippi; and a low-water mark was pointed out which showed that the surface had at times receded to $13\frac{7}{10}$ feet below high water in the river. If we assume that the mean surface of the lake is eleven feet below high-water, and the distance from the river to the lake in a right line, five miles, we shall have data near enough to the precise facts for all practical purposes.

The following section, (fig. 9) is a correct profile of the ground from the Mississippi to the gulf, showing the level of both as the water stood on the 7th day of April last.

It will be perceived from this profile and description, that if the levee that now confines the water to the channel of the river were removed, the water would rush from the river towards the gulf in a column six feet deep. But if the earth back of the levee were excavated to the level of the swamp, or cut down to a level 10½ feet below the high-water surface of the river, the flood would pour through this opening in a column 10½ feet deep.

The average fall of the surface, from the river back to the level of the gulf, before the water of the Mississippi had suffered any reduction, (if the opening were made suddenly) would be 2½ feet per mile. The velocity of the surface current would be, before this reduction would have place,

$$v = \frac{8}{10}\sqrt{2.2\times10.5} + \frac{2.2\times10.5}{20} = 5 \text{ feet per second.}$$

If the levee were removed over a space of 5,000 lineal feet, the area of the outflowing column would be 52,500 square feet, and the discharge, consequently, about 210,000 cubic feet per second. But the actual discharge, while the length of the opening continued to be 5,000 feet, would be materially less than this amount; for the surface of the Mississippi would soon be depressed, and the depth and velocity of the column, of course, would be simultaneously reduced.

It is not at all probable, however, that the surface of the river could be reduced by this process more than 2½ or 3 feet, unless the torrent should be found to tear up the soil and cut a deeper outlet into the gulf. This is not likely to occur to any considerable extent if the force of the stream be not aided by artificial appliances. But a deepening can be effected by cutting

trenches from the river to the bayous which run through the swamps; clearing off the timber and loosening up the surface soil; confining the water between lateral levees extending from the Mississippi to the gulf shore; and so placing movable obstructions in the outlet, that the water, in undermining them, might tear up the bottom.

It is the opinion of the writer that it will be practicable, for an outlay which will not be unreasonable, to form a vent at this point which will obtain a depth nearly or quite equal to the difference between the high-water level of the river and the bottom of Lake Borgne near the shore, or about fourteen feet; and that such an outlet, thus increased in depth, will effect a reduction of the surface of the Mississippi, at high water, of not less than four and possibly five feet—an effect sufficient to secure the safety of New Orleans and the whole coast below the city, and some considerable distance above, for a very long period.

But it is not the purpose to recommend assigning any limit to the discharge that is to be poured through this outlet into Lake Borgne. It is proposed to cut boldly here; to encourage the action of the water by every effectual expedient, so as to reduce the surface of the river down as nearly as possible to the level of the gulf. All the water that is vented at this point, all the reduction of surface that is effected by this vent, will be productive of good. There is here no interest to be injured but that of the few individual proprietors whose estates will be appropriated, and to whom, of course, compensation must be made.

An apprehension is often expressed that the withdrawal of a large volume of water from any part of the channel will cause an increase of the bars at the mouths of the Mississippi, and therefore prove injurious to the navigation.

But it has been shown by the writer, in another report, that these bars are not produced by the destruction of the velocity of the river, where the fresh water meets the sea, but by the refluent under-current which is set in motion by the out-pouring floods of the Mississippi. It has, in fact, been shown that the bars at the embouchures of the passes cannot be reduced in height by increasing the velocity of the river over them, and will not be increased in height by reducing the velocity.* On the contrary, if the river could be made to discharge a large portion of its burden by some other channel, the depth upon the bars would be increased by the action of the sea, which would then set higher up; and if the river could be turned off entirely and let into Lake Borgne, the bars which are thrown out by the Mississippi, and maintained in the deep water of the gulf by its power, would be swept off by the waves, when a heavy sea would set into the mouth of the river, unresisted by the descending flood.

There is another point worthy of attention in discussing this subject, and which has been duly considered. The depth of Lake Borgne is very inconsiderable—varying from six to twelve or thirteen feet; and it would, therefore, if made the recipient of the mass of water which it is proposed to discharge into it, be soon filled up with the deposites from the fresh water of the river. This is an inevitable result, and the effect of the outlet, from this cause, would be gradually diminished. As the lake would fill

* See report to the War Department, "on the improvement of the navigation across the bars at the mouths of the Mississippi river."—Ex. Doc. No. 17, 31st Congress, 2d Session, page 12. By Charles Ellet, jr., civil engineer.

up, the water discharged would flow through a channel of its own, between the natural levees which would be formed—as the banks of the Mississippi and those of all of its bayous have been formed—from the deposites of the water flowing off laterally from the course of the outlet. This channel would gradually extend through the whole length of the lake, carrying with it a delta like that which characterizes the embouchure of the Mississippi, until it would ultimately, and indeed at no distant day, reach the deep water south and east of Ship island.

It is the belief of the writer that it will be found practicable, by dint of labor, and cutting boldly at the borders of the Mississippi, to make an outlet into Lake Borgne, which may be encouraged to increase until it eventually becomes one, if not the greatest, of the navigable passes to the gulf. This indeed should be the aim: and we should be encouraged to proceed with the plan from the consideration that it is really the only great outlet that can be made from the Mississippi that will be extensively beneficial to the city of New Orleans and the adjacent coast, and yet injure no existing interest, which we may work upon without cessation, doing some good all the time and endangering nothing. We shall presently see that those other outlets which it is the duty of the writer to propose, have not this recommendation.

OF THE ENLARGEMENT OF THE PLAQUEMINE.

Next in value to the outlet which is recommended below New Orleans, in the estimation of the writer, will be found an enlargement of the area, and consequent increase of the present discharge, of the Bayou Plaquemine—one of those high-water vents left open in the original condition of the delta, and which have not yet been closed for local purposes.

It was a part of the natural adjustment of this great stream, to exhibit numerous openings through the elevated banks which form its coasts; where, in times of flood, as the water rose, it obtained exit by lateral channels which discharged into swamps, bays, or arms of the gulf. These openings, fifty years ago, were very numerous, and were to be found on both sides of the Mississippi, from the mouth of Red river to the Balize.* But, in the progress of society, the population which, allured by the productions of the sugar lands, took possession of the banks of the Mississippi, closed up these outlets, by extending levees across them; so that, out of forty or fifty, or more bayous, which formerly served to relieve the overcharged channel, there are now left but *three* which still act in high water for the depletion of the river. Of these three, it is here recommended to select the Bayou Plaquemine as the one most suitable, for divers reasons, to be increased in capacity, and made to replace a portion of those inactive outlets which have been destroyed by the levees.

The ruling motive for the preference here given to the Plaquemine is the peculiar facility which its channel offers for prompt and economical enlargement. It has a more rapid fall than either of the other open bayous. It

* The late John McDonough, in reply to the questions proposed by the joint committee of the legislature of Louisiana, says: "When he first travelled the banks of the Mississippi, fifty years since, on horseback, he was forced to swim his horse across at least twenty or thirty different bayous—some of them fifty to sixty feet in width—which crossed the path he travelled and entered the river." These bayous were on the west bank, between the Bayou Plaquemine and Red river, and have all been stopped up in the progress of improvement.

has a shorter route to the sea-level than that traversed by either of the other existing outlets. It passes through a district less highly improved than would be encountered on any of the other open or abandoned bayous. The volume of water which it discharges can, therefore, be more cheaply augmented than that discharged by any of the other natural vents.

The descent of the Plaquemine, from its source at the town of Plaquemine, on the Mississippi, to the Indian village, is, at high water, nineteen feet.

The distance between the same points, by a survey following the course of the stream, is eight and one-half miles. The descent in that distance is, therefore, at the average rate of 2.25 feet per mile; which is about ten times as great as the average slope of the Mississippi, in this part of its course.

This rapid descent of the Plaquemine renders the enlargement of its channel a work of singularly easy execution. The velocity of the current is now, in high water, from six to eight feet per second, and in places considerably greater. Its depth varies from twenty-five to forty feet.

To enlarge this channel, nothing is necessary to be done but to cut off two or three short bends, and then promote the attrition of the current against the salient points which it is proposed to remove.

The material which may be excavated should be taken from the north side of the bayou, where there are few improvements to be injured; and should be deposited in an ample levee, on the south side, so as to protect the country there from overflow.

The water may be forced to assail the banks, either by cutting them down perpendicularly, during low water, so that they may be undermined and fall in as the stream rises: or the object may be effected at high water, by anchoring stout barges against the points to be removed, provided with wheels to be turned by the stream, and armed with appropriate scrapers to cut away the soil as they revolve and the current rushes by. The velocity is now, at surface, in some places, seven or eight miles an hour, and it can be speedily increased to an average of seven miles by removing the projecting points, cutting off the short bends, and slightly increasing the depth across the bar at the source of the outlet.

By the exercise of ordinary prudence, there need be no apprehension that the water will scour out its own channel faster than is desirable. On the contrary, it will require vigor and skill to increase the discharge at this point fast enough for the relief of the coast. The work of enlargement will, however, be arrested by other considerations than any fear that may arise lest the Mississippi should turn its channel down this bayou, and find a permanent and principal passage, through Grand lake, into the Atchafalaya bay.

It is not to be assumed that the water of the Mississippi can be discharged to any great extent through the Plaquemine into Grand lake, without harm to other existing interests. There is, in fact, no point on the coast above New Orleans, at which a sufficient portion of the high-water burden of the river can be withdrawn to afford essential relief to the population there, without causing injury to some other community and the destruction of some other interests.

The most that can be said, on this head, in favor of the Plaquemine over other outlets that might be proposed, is, that a greater interest will be re-

lieved, and a smaller interest will probably be entitled to compensation for damage sustained, here than elsewhere.

It is this consideration, and none other, that will arrest the discharge which ought to be poured through the Plaquemine into Grand river. But this consideration—the damage to property on the Teche, and other bayous tributary to Grand lake, Berwick's bay and the Atchafalaya river—will be sufficient to compel us to arrest the discharge before the volume and speed of the current can lead to any serious apprehension of other dangers.

It will be observed that the water which is discharged by the Plaquemine is first received by Grand river, from which it is conveyed by numerous bayous into Lake Chicot and Grand lake. These bayous find their way through great tracts of swamp, or inundated lands, into numerous shallow lakes, which are destined at no distant day to be themselves transformed, by the deposites which are left in them by the water of overflow, into similar swamps.

But it will be proposed, presently, to enlarge the Atchafalaya, another of the three existing outlets of the Mississippi, which also empties into Grand river, and through the bayous leading thence into Lake Chicot and Grand lake. It will be seen, therefore, that Grand river is to become the recipient of all the waters of overflow which can be discharged by artificial or natural vents above New Orleans.

It is neither the intention nor the hope to obtain much more relief by means of an enlarged outlet at Plaquemine than that which is now rendered by the crevasses; but it is deemed advisable so to enlarge the capacity of this vent, that it may be relied on to discharge at least as much water as now ordinarily finds its way to the swamps through breaches in the levees.

This will be effected when the capacity of the Plaquemine is made about four times as great as it now is, or when its present extreme high-water discharge is increased from about 30,000 cubic feet to about 120,000 cubic feet per second. It may, indeed, eventually become advisable to draw off a still greater volume at this point, if, after the amount of injury that may be anticipated by a given augmentation of the discharge has been accurately ascertained, it be deemed prudent to make remuneration for that injury, and push the enlargement of the outlet still further.

This, however, may be left for future consideration, after the first relief has been obtained, the immediate wants of the coast have been met, and the adjacent levees have been rendered secure;—after the Atchafalaya has been enlarged as far as may be found expedient: and experience, under the new order of things, shall have indicated the measure of further enlargement that would be proper.

There can, however, be no reasonable objection offered to increasing the draught through the Plaquemine until this bayou discharges into Grand lake a column equal to that which is ordinarily received by that basin from the crevasses in the levees. And this is what it is here proposed to do: to increase the area and discharge of the Plaquemine until it can be regarded as a reliable substitute for those disastrous crevasses by which the channel of the river is now annually relieved. This condition will exact a breadth at surface of six hundred feet, and an average central depth of forty feet, or that the area of the section of the Plaquemine be made very nearly equal to the present area of the Atchafalaya.

OF THE ENLARGEMENT OF THE ATCHAFALAYA.

The Atchafalaya is by far the largest of the existing or former outlets of the Mississippi; and it has been often proposed to resort to its channel as the best and most efficient drain for the floods which now threaten the country below its source.

In concurring with this popular idea, so far as to advise a commencement of the gradual and progressive enlargement of this great stream, it is not intended to represent the work as easy to accomplish, or in itself an effectual remedy for the floods of lower Louisiana.

It will, in fact, be found to be an exceedingly difficult and costly undertaking, and one which will need to be conducted cautiously, and not too rapidly, if it is to be effected without serious injury to the region through which the water is to be conveyed.

The Atchafalaya leaves the old channel of the Mississippi about two miles below the mouth of Red river, and 310 miles, by the windings of the channel, above the Gulf of Mexico. It flows nearly in a southwardly direction; and when the Mississippi is swollen by floods, it serves as a natural vent for a portion of the present excess of water, of which it bears off a large volume to the sea. At its source, its average surface width in extreme high water is about 600 feet; its depth 55 feet; its slope six inches per mile, and its discharge not less than 85,000 cubic feet per second. It is about equal, measured by the area of its channel and the volume of water which it conveys, to one-twelfth part of the capacity of the Mississippi above New Orleans.

It has been long supposed that the Atchafalaya was the ancient bed of Red river, when that stream had no connexion with the Mississippi, but found its way to the Gulf of Mexico by an independent channel. The union of the two streams—the Mississippi and Red river—is accounted for in this theory, by the supposition that, at the point where their waters now mingle, their channels then exhibited opposing flexures, and the current gradually cutting away the intervening soil, brought the streams together and made their waters common.

This has become of late years a very popular theory, and is supported by several plausible arguments. The position of the mouth of Red river on the one hand, and that of the source of the Atchafalaya on the other; the direction by which Red river enters, and that by which the Atchafalaya leaves the old channel of the Mississippi, correspond perfectly with the assumption, that the curves of the two adjacent streams gradually approached until they finally cut into each other. Besides, the color of the soil composing the west bank of the Atchafalaya at its source, indicates clearly a Red river origin. But, notwithstanding the plausibility and force of these facts, they are not at all conclusive, but apply with equal directness to another view that will be here suggested.

In fact, the hypothesis which attributes the original formation of the Atchafalaya to the discharge of Red river, is found, on a careful examination, to be wholly untenable.

It results from actual measurements of the channels of these two rivers, that while the Atchafalaya at its source has a prevailing depth at high water, in mid-channel way, of only about fifty-five feet, Red river at its mouth, only three miles distant, exhibits a depth of more than one hundred feet; that, while the Atchafalaya is confined within a channel less than 600 feet wide at

its surface, in high water, the width of Red river between banks a mile above its mouth is more than 1,100 feet: and that while the descent of the Atchafalaya at or near its mouth is six inches per mile, that of Red river, where it enters Old river, is, at low water, less than one inch per mile.

The hypothesis of a former continuous channel, common to these two streams, so different in all their features, must therefore conceile a sudden and remarkable change in the character of the supposed ancient Red river, at the precise point of the present junction of that stream with the Mississippi. Such a change, and the exact coincidence of that change with the point of accidental contact of the two shifting channels, is, indeed, not impossible; but it is, at least, quite improbable. A less violent and much more safisfactory theory for the existence of the Atchafalaya—one of the most remarkable features of the Mississippi—may be suggested, though the writer has not had full opportunities to submit it to a very rigid inspection.

Black river, the proper continuation of the Washita, corresponds much more closely in the dimensions of its channel with those of the Atchafalaya, than Red river. The general direction of the Washita is from north to south —corresponding well with the general course of the Atchafalaya.

The idea has impressed itself upon the mind of the writer that, in the original condition of the delta, the *Washita*, as well as Red river, descended by an independent channel to the gulf, which then perhaps set up through a bay as far as the head of Lake Chicot.

The Mississippi pursued its present general direction. Red river had also its own independent channel to the gulf, in the present valley of Teche, where it has left abundant traces of its course in the composition of the soil, from above the rapids at Alexandria down to Berwick's bay. The Washita was thus an independent stream, descending to the sea between Red river and the Mississippi.

According to this hypothesis, the Washita and the Mississippi, by the gradual approach of opposite bends, ultimately united their waters, and the Washita was, so to speak, cut in two—the northern part afterwards serving as a feeder to the Mississippi, and the southern end acting as an outlet for its surplus water in times of flood.

The Washita having been a stream of smaller class than Red river, may be adduced as a reason why the present channel of the Atchafalaya, which was formed to accommodate the volume which that river, and not Red river, brought down, is insufficient for the discharge of the present volume of Red river. The Washita flowing directly down the plane of the delta, which it has been shown descends at the rate of eight inches per mile, accounts for the greater fall of the Atchafalaya, which takes the same direction parallel with the dip of the same plane.

Subsequently to the junction of the Washita and the Mississippi, Red river—then continuing on below Alexandria, in the same southeasterly direction which it still pursues above that point—flowed over its natural levee, and, taking an eastwardly direction through the swamps, united its waters with those of the Washita at the present mouth of Black river. Under this hypothesis, the increased volume below the confluence of these streams produced the larger channel known as Red river, which even now is scarcely sufficient to accommodate their collected waters.

According to this view, which is suggested as the most plausible explanation of the existence of the Atchafalaya, that stream was the ancient channel of Black river; and the present channel of Red river, below the

mouth of Black, was subsequently enlarged by the union of the waters of the Red and Black.

These considerations are not without a practical value in the present discussion. If it be true that the Washita had an ancient independent outlet through the Atchafalaya, the fact that this outlet has not increased in capacity since its function has been to give passage to the waters of the Mississippi, which it conveys to the sea-level by a slope twice as great as that of the Mississippi itself, is further evidence that the apprehension so often expressed, that it may ultimately absorb the Mississippi, is without stable foundation.

In fact, it is not yet demonstrated that this outlet may not have been one of those original vents which, like the Plaquemine, Manchac and La Fourche, and numerous other bayous, were formed as the outlets near the mouth of the river are now formed, during the deposition of the soil, and for the purpose of relieving the channel of its high-water load. Be that as it may, the Atchafalaya has existed for ages, and now exhibits signs rather of a progressive contraction than an enlargement of its area. There is, in fact, not only no reason to believe that it will ever open its own channel wider and deeper, but scarcely even substantial ground to hope that this result can be materially promoted by any moderate amount of cost or labor.

The Atchafalaya, at its source, draws from the Mississippi, in very high floods, about 85,000 cubic feet of water per second, or about 8 per cent. of the actual discharge of the main channel of the river. But the right or west bank of the bayou is overflowed in high floods by the backwater of the Mississippi, or by that of the Red river; and below the mouth of Bayou de Glaise, five miles from its source, the extreme high-water discharge is consequently increased, by accessions from Red river, to about 140,000 cubic feet per second, or 13 per cent. of the total discharge of the main channel of the river.*

It is by observing these accessions from Red river, when the Mississippi has begun to fall, and the confined water of Red river obtains vent, that we are enabled to account for that red deposite on the west bank of the bayou, which has been so long regarded as conclusive evidence that this was once the proper channel of Red river itself. While the bayou is drawing in the water of the Mississippi at its source, the water of Red river, charged with its characteristic deposite, and deeply colored, flows rapidly through the swamps, and pours over the whole west bank of the Atchafalaya for a space of four or five miles, from Old river down to Simmsport, and slowly mingles with that of the Mississippi. It is from this Red river overflow that the west bank of the Atchafalaya receives the red stain. But the overflow from that quarter diminishes as we descend, and the red deposite becomes also less and less clearly defined.

In this, the upper part of its course, the Atchafalaya may be easily and cheaply enlarged. The purpose may be effected by first cultivating its borders and clearing off all vegetable growth, and then cutting down the salient points, and encouraging the action of the water upon them. But the difficulty of converting the stream into an efficient outlet is not found here at its

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* When the Atchafalaya was gauged, (April 26, 1850,) the water had fallen at its source 2.2 feet. The actual discharge was then found to be—

At its source,	- -	77,100 cubic feet per second.
Below Bayou de Glaise,	-	122,700 " " " "

No observation was obtained at the time of extreme high water.

source, but increases from mile to mile as it descends, until it discharges itself, by numerous mouths, into Grand river, and again, through numerous bayous leading from that river, into the lakes which intervene between it and the gulf.

The real difficulty consists in the fact, that the Atchafalaya loses its importance and its power as it advances below the Bayou de Glaise. It yields the water which it had drawn from the Mississippi and Red river, to numerous outlets, which diverge from it to the right and left; and as it received accessions from Red river, which were discharged into it from the swamps above, so it discharges them again over its banks into the swamps of the interior below.

In passing down this stream in the latter part of April, 1851, when its surface had fallen 2.2 feet from its extreme high-water mark of that year, at Old river, and one foot at the head of Grand river, and gauging its volume from point to point, the following results were obtained:

The Atchafalaya drew from the Mississippi, at its source, in Old river	77,100	cubic feet per sec.
It received accessions from Red river in the first five miles, which increased the discharge to	122,700	" " " "
At a point one mile above the Raft, the losses caused by lateral drains had reduced the discharge to	88,600	" " " "
At Picket's, one mile below Bayou Rouge and Bayou Latinache, its volume had been reduced down to	67,900	" " " "
At a point just below the source of Alabama bayou, it was found to be only	41,870	" " " "
Nine miles below the mouth of Bayou Little Devil, and half a mile below the re-entrance of Bayou Alabama, the discharge of this great stream had dwindled down to	19,400	" " " "

In addition to the effect of these continual losses, by which its volume is reduced to less than the *sixth part* of that which its channel discharged at Simmsport, the power of the current is still further reduced by a corresponding change in its rate of descent.

The actual descent in the lower part of the course of the stream was not measured, but the velocity was frequently tested; and, compared with the observations taken in the first twenty miles below Old river, they showed a falling off, in the speed of the current, of nearly one-half.

To make the main channel of the Atchafalaya capable of accommodating the volume of water which even now enters from above, the remaining obstructions at the "Raft" must first be removed, and the capacity of the stream must be increased an average of *fully three-fold* its present value, for a distance of forty miles. If, therefore, it should be attempted, as has been suggested, to produce the enlargement by pouring in more water at the source of this outlet, at Old river, without first preparing the channels below to give it vent, we shall overflow a great extent of country, and retard for years, if not permanently, its proper and necessary drainage.

This is one of those cases in which every consideration of prudence and economy urges the prosecution of the works of reclamation and enlargement *below*. The Atchafalaya and the Plaquemine discharge their waters at the opposite extremities, and through various bayous, at intermediate

points along the course of Grand river. This river is now, in fact, the recipient of all the water of overflow, and the crevasse water, together with that of the natural outlets of the Mississippi and Red river, from the source of the Plaquemine to the Red River rapids. The water thus received by Grand river from so many sources, is discharged from it, through numerous bayous and small lakes, into Lake Chicot and Grand lake. These bayous are very crooked, and frequently obstructed. Their descent is small, and the current passing through them is, in many places, extremely sluggish.

If the enlargement of the Atchafalaya be undertaken, these bayous must be simultaneously relieved of obstructions to the passage of water through them, straightened and enlarged; so that the additional volume of water received by Grand river may flow more readily into the lakes, and not spread over, and forever destroy, the great area of swamps, yet reclaimable, by which these lakes are surrounded. The work of enlargement may then proceed upwards, along all the bayous which now drain the Atchafalaya, and which will still be required to vent the increased volume which it is to be made to carry.

It is not to be supposed that this work can be accomplished speedily, at trifling cost, or without involving much local damage. The accomplishment of the labor, so as to produce appreciable effects, will require several years, however ample the means may be, or with whatever vigor the work be pressed; and a portion of the country will inevitably be flooded, however prudently its execution may proceed.

It was no part of the duty of the writer to investigate in detail the damages that may accrue from the accomplishment of this plan. It was sufficient to see and to know that the preservation of great interests from destruction will ultimately compel a resort to this measure. And as it is clearly in the power of those who control the progress of the work to arrest it whenever the damage threatened exceeds the value of the results produced, it seems unnecessary to delay it for minute and doubtful estimates.

But, as already intimated, the enlargement of the Atchafalaya by any justifiable process, will prove to be a slow and expensive undertaking, involving great labor and loss of life. The work, therefore, though necessary and proper to be commenced, will not afford that prompt relief which is demanded by the present emergency. The country needs immediate protection against present distress, and effectual guarantees against approaching dangers. For these we must look to the Plaquemine as the only point, on the west side of the river, at which we can relieve the lower coast with the necessary despatch. Another outlet will be presently suggested, in case of great emergency, as a temporary expedient; but the Plaquemine is, beyond all comparison, the channel by which we can most confidently undertake to produce visible and valuable results for moderate cost and with the necessary rapidity.

The Atchafalaya, when enlarged, will be much the most important outlet that can be obtained; because it draws off the water at the highest accessible point on the river. It is, therefore, not to be neglected; but is earnestly recommended here as a point at which the work should be commenced without delay. The superior merit of the Bayou Plaquemine consists simply in the fact, that, by its enlargement the lower coast can be more expeditiously relieved than by any other possible outlet.

But let it be observed that neither the Plaquemine nor the Atchafalaya, nor both together, can be relied on to give vent to the volume of water

which must be drawn from the channel of the Mississippi, when the system of levees now in course of construction along the upper coasts is carried out, and the floods are increased, as they are destined to be increased, by the destruction of all the great natural reservoirs of the delta.

If we allow for the increased duty of the Atchafalaya, 150,000 cubic feet per second, we must assume that the capacity of the channel of that bayou will be made thrice as great as it is now. It is extremely doubtful whether the current can be made essentially to increase *the depth* of the channel; and if not, then the increased area must be obtained exclusively by an increase of the width: and the breadth of the surface of this great river must consequently become about sixteen hundred or one thousand feet greater than it now is. This implies the excavation of a new channel one thousand feet wide and about fifty feet deep, and seventy or eighty miles long. If the water can be made to do the chief part of this labor, with the needful rapidity—which is the confident belief of others, and the hope of the writer—it will be cheaper and better to resort to this plan, to obtain extensive and adequate security, than to any other which has yet been proposed. But, if this hope should be disappointed, and the labor of making the water act with adequate rapidity in the lower part of the stream should prove much greater than is expected, or greater than can be endured, it may result that after completing the outlet into Lake Borgne and enlarging the Plaquemine, and commencing a guard levee of ample dimensions, *reservoirs* will then be the cheaper, as they will assuredly be the more certain, reliance for further protection.

We shall again recur to this question under another division of the subject.

OUTLET INTO LAKE PONTCHARTRAIN.

Next to the enlargement of the Plaquemine, by far the most efficient outlet that can be made, at reasonable cost and in a reasonable time, for the discharge of a portion of the surplus water of the Mississippi, will be a high-water opening from the bend at Bonnet Carré into Lake Pontchartrain. This expedient has been frequently proposed and elaborately discussed by others, but without the aid of previous instrumental examination.

The leading and true argument in favor of this plan is, unquestionably, the great rapidity and ease with which it can be accomplished. The prominent objections to it, in the view of the writer, are—

1st. That the point where the outlet is proposed to be made, is too near the gulf to afford relief to any great extent of river coast.

2d. That the deposites which will be discharged by the Mississippi into Lake Pontchartrain, will at first impair, and ultimately destroy, the navigation of the lake, which must always be of great value to New Orleans.

3d. That the water withdrawn from the river will so raise the surface of the lake as to inundate the swamps on its coast, and in the rear of New Orleans; rendering it necessary to enclose the city on all sides within a levee, and rely altogether on the draining pump to relieve it from the surface and sewerage water.

The distance from the Mississippi, at Bonnet Carré, to Lake Pontchartrain, is four and a half miles. The descent from the level of the high water of 1849, in the river, to the surface of the lake, at the date of the survey, was $16\frac{86}{100}$ feet. The fall per mile from the high-water surface of the river to that of the lake is, therefore, $3\frac{37}{100}$ feet.

The lake, when this level was taken, was considered to be about two feet above its usual low-water stage.

When the Mississippi is in full flood, its surface is about six feet above the natural bank at the proposed outlet at Bonnet Carré; and the natural bank, or immediate coast of the river, is here the highest part of the plane which slopes back from the edge of the river to the lake. The water of the Mississippi is, therefore, only prevented from pouring over its borders in a column six feet deep, and discharging itself at the level of tide-water in Lake Pontchartrain, by the line of embankment which the planters have raised for the purpose of protecting their fields from inundation. The floods of the river might be easily discharged in part at this point; where they would reach the level of the sea in four and a half miles, instead of following the windings of the river for a distance computed at one hundred and fifty miles.

The profile shown in fig. 2 will exhibit a correct section from the Mississippi to Lake Pontchartrain, at the point where the crevasse of 1850 occurred, and where a permanent outlet is so often proposed.

All that is necessary to be done to relieve the Mississippi at this point of a portion of its surplus water, is to cut two trenches from the river to the lake, and use the material taken from them to form two parallel levees, at the distance of four thousand or five thousand feet asunder, and then remove the artificial embankments on the borders of the river, and let the Mississippi flow down the intervening plane into the lake.

In truth, nothing would be easier than to protect the country many miles above and below Bonnet Carré, or, in some degree, from the mouth of Red river to the sea, by opening a vent in the mode here described,—for this opening may be encouraged to increase to any desirable extent.

Yet the objections already enumerated are so serious that a resort to this measure, so simple and so certain to produce prompt but limited results, cannot be recommended here. At least, it cannot be recommended as a permanent improvement and a reliable plan, though it may ultimately be adopted, should events arise to justify it, as a temporary expedient. Should it be found, after the Plaquemine has been enlarged to the greatest admissible limit, and the outlet proposed below New Orleans has been effected, and the other plans which will be presently discussed have been carried to their utmost limit, that the section of the Atchafalaya cannot be increased fast enough to give proper vent to the increasing floods, then, and in that event only, will it be advisable, in the view of the writer, to tap the river at Bonnet Carré, and turn a portion of the remaining surplus water into Lake Pontchartrain.

The outlet proposed to be made by the enlargement of the Plaquemine, will draw off the water at a point seventy-five miles higher up the Mississippi than that at Bonnet Carré, and it will therefore afford relief to seventy-five miles more of the coast. The cost of the work will not be greater than at Bonnet Carré, for we have the present channel, and the force of the water now running through the Plaquemine, to aid the undertaking.

The filling up of Grand lake and backing the water up the Teche will be productive of less injury to property, and will impair a navigation of less value to Louisiana, than its admission into Lake Pontchartrain. The enlargement of the Plaquemine to the utmost admissible limit, should therefore precede the opening of any outlet at Bonnet Carré.

The absolute rate at which Lake Pontchartrain will be filled up by

deposites, in case a portion of the increasing floods should be discharged into it, is not deemed of primary importance. It is enough for us to know that very great deposites will be made, and that they will not be left in regular strata over the whole bed of the lake, but in the form of *bars* and *islands*, which will speedily obstruct the navigation and render it always uncertain.

The quantities of earthy matter contained in the water of the Mississippi, in different conditions of its surface, have been investigated by several scientific gentlemen, whose results are not widely different. Preference is here given, however, to those published by Professor Riddell, of New Orleans, who, to his scientific reputation and skill as a manipulator, has superadded the claim to confidence which is due to great zeal in this subject.

The experiments of Professor Riddell have led to the conclusion, that the proportion of sedimentary matter to the weight of Misssissippi water containing it, is as follows:

Water 1, maximum weight of sediment $\frac{1}{693}$.
Water 1, mean weight of sediment $\frac{1}{1155}$.
Water 1, maximum weight of sediment $\frac{1}{2310}$.

When solidified into coherent earth, at a mean, it was found that the *bulk* of the sediment was equal to $\frac{1}{2000}$ part of that of the water in which it was suspended.

But the greatest amount of sediment is found when the river is in flood; and it is when in that condition that the discharge into the lake would take place. We may assume, therefore, from these experiments, that when the river is in flood, the bulk of sediment would be to that of the water containing it, about as 1 to 1500.

We will assume, that if it should ever become advisable to draw off any portion of the surplus water of the Mississippi through Lake Pontchartrain, it will be necessary, in order to obtain any essential relief, to give vent to at least 100,000 cubic feet per second at that place. An outlet discharging less than that would produce but little impression upon the future floods.

There are 86,400 seconds in a day. The daily discharge of the outlet will then be 8,640,000,000 cubic feet.

Of this volume, the $\frac{1}{1800}$ part will be coherent earth; or $\frac{8640000000}{1800} =$ 4,800,000 cubic feet, of sedimentary matter, will be deposited in the lake each day that the outlet is discharging at the rate of 100,000 cubic feet per second. If the annual discharge of the outlet average this amount for sixty days, the total deposite for the year will be 288,000,000 cubic feet.

Now, the average depth of Lake Pontchartrain is thought to be ten feet. Its area, according to La Tourette's map, is about 530 square miles.

A square mile contains 27,878,400 square feet.

The annual deposite produced by this outlet would then be sufficient to raise up an island one mile square and ten feet high, from the bottom to the surface of the lake.

These deposites would be irregular. In the course of a hundred years, there might be more than a hundred islands and shoals scattered over the lake, of which the height, and sometimes the position, would be changeable, and the channels therefore shallow and uncertain. Without entering into any minute computations, it is clear that an efficient outlet at Bonnet Carré is incompatible with the permanent maintenance of the navigation of Lake Pontchartrain.

The ultimate loss of this navigation is, then, one of the sacrifices which must be encountered, when we resort to this unnecessary and apparently superfluous expedient.

The increased elevation of the surface of the lake which will be produced by this increased discharge, has already been alluded to.

Lake Pontchartrain is connected with the Gulf of Mexico by two narrow passes, known as the Rigolets and Chef Menteur. The tides of the gulf set up through these passes, and produce corresponding tides in the lake.

The volume that is admitted into the lake by a high-water outlet from the Mississippi, must flow into the gulf through these passes; and consequently, the surface of the lake must rise, until a sufficient *head* is obtained to produce a velocity through the passes, adequate for the discharge of the additional volume admitted.

Now, it has been shown by Professor Riddell, who has investigated one branch of this subject very beautifully, that by the best data attainable, without an actual survey of the passes, the elevation or head necessary to produce the velocity requisite for the discharge of one hundred thousand cubit feet per second, would be, by the formula of Wiesbach, but about one inch and a half.

But, admitting the fact, that if the two surfaces—that of the lake and that of the gulf—were permanent and steady, as is assumed in this computation, this would be the whole effect due to the admission of this volume of water, we are not thence hastily to conclude that such will be the practical result. This problem is a much more complicated one, and requires for its solution a study of *the tides* of the gulf and those of the lake.

If the surface of the gulf were not affected by the tides nor by the winds, the elevation of the surface of Lake Pontchartrain, due to an outlet from the Mississippi discharging one hundred thousand cubic feet per second, would not, perhaps, be increased more than two inches. But the increased elevation due to this discharge is made much greater by the tides and winds. It is not intended here to say that the increased elevation of about two inches, which the assumed supply from the Mississippi would produce, is to be added to the elevation caused by the tides and winds, in order to obtain the total elevation. That is not the point. But it is the intention to say, that the tides and the winds greatly increase the elevation due to the discharge through the inlet—greatly increase the effect of a given volume admitted from the Mississippi. The problem here is not to compute the elevation of the lake, or the *head* that is necessary to produce a sufficient velocity through the passes to discharge the volume that it is proposed to introduce through the artificial inlet, but the *increased elevation* which is necessary to produce the *increased velocity over and above the tidal velocity*.

Thus, to reduce the surface of the lake twelve inches, there must be driven through the passes by the refluent tides, or by the winds, a volume of water equal to $530 \times 27{,}878{,}400 = 14{,}775{,}552{,}000$ cubic feet. If this volume flow out of the lake through the passes in eight hours, we shall find, by dividing by 28,800, (the number of seconds in eight hours,) $\frac{14775552000}{28800} = 513{,}000$ cubic feet, for the volume which must be discharged through the passes in each second of time. Now, a variation of twelve inches in eight hours, in the height of the lake, is no unusual thing. To give the velocity necessary to produce this discharge, Lake Pontchartrain

must be elevated above the level of the gulf, according to the table of Professor Riddel, which is here adopted as a sufficient approximation, no less than $3\frac{36}{100}$ feet.

If now we superadd to the volume pouring through the passes under the action of tide and wind, a volume of 93,500 cubic feet per second, due to a crevasse or an outlet, we shall have, by the same table, a further increase of elevation amounting to sixteen inches. (See note G.)

In fact, a discharge of one hundred thousand cubic feet per second will effect the elevation of the high tides of the lake, by the best data that can be obtained without a thorough survey of the passes, not less than eighteen inches. And even this limit will be occasionally exceeded; as when a coincidence occurs between the maximum discharge from the artificial inlet into the lake, high tides in the gulf, and *floods in the natural feeders* of the lake—which are quite too important to be entirely overlooked.

It will be exceeded also for another reason: the water that will be received from the Mississippi will enter near the head of the lake: and to obtain a passage through the lake, it must communicate a certain velocity to the whole body of water in the lake. To produce this velocity will require a corresponding elevation of the surface at the head of the lake. In estimating this elevation, we cannot regard the entire section of the lake as a mere conduit, having a given uniform velocity seaward.

There will be an outward current passing somewhere through the lake, with eddies, or counter-currents, near its borders. The elevation will be again materially increased from this cause. The writer hesitates, in anticipation of precise surveys, to assign a definite limit to the increased elevation of Lake Pontchartrain, which must be occasionally anticipated from the discharge of one hundred thousand cubic feet per second into it, by an outlet from the Mississippi at Bonnet Carré. But, from the best data now attainable, it cannot be set down at less than two feet.

In view, then, of the facts, that such an outlet as is here discussed must inevitably involve a destruction of the navigation of Lake Pontchartrain; ultimately convert it into a swamp; must greatly increase the ordinary height of its surface when the outlet is active; cause the entire shore to be leveed, and the cost of mechanical drainage to be greatly increased; without affording as effectual relief as can be obtained at Plaquemine without either of these sacrifices,—the opinion is confidently expressed, that this expedient should be postponed until it is found to be necessary and indispensable. This necessity, there is every reason to believe, may never occur.

OUTLET AT THE MOUTH OF THE ARKANSAS.

Before dismissing the subject of outlets, it is proper to say, that although examinations have only been made with a view to the adoption of this remedy at and below the source of the Atchafalaya, it is by no means certain that the safety and the proper drainage of the country above may not compel a resort to this method for relieving the Mississippi near the mouth of the Arkansas, by a great conduit leading thence to Red river. If this should ever be done, it ought to be after the work of enlarging the Atchafalaya shall have progressed far enough to give a certain vent to the increased volume which this new outlet will bring into Old river.

This idea suggested itself with some force to the mind of the writer at a

late period, and after becoming satisfied that the mouth of the Arkansas is at no distant day to become the scene of a vast collection of water, which must either be discharged by an appropriate permanent vent, or through crevasses, whence it will inundate the estates on the Bartholomew, Mason, Tensas, and other streams between the Arkansas and Red rivers. No investigation of this subject has, however, been attempted. To be made properly, special surveys, and a thorough reconnoissance of the parishes which the proposed outlet will traverse, will be needed.

OF THE OPENING OF THE BAYOU MANCHAC.

It has often been proposed to relieve the Mississippi by re-opening the bayou Manchac, one of those natural outlets which formerly drew off a small volume of water, and discharged it into Lake Maurepas by the channel of Amite river. It was not found to be necessary to make any extensive examination of this bayou, which was originally very insignificant, and is now entirely unfit for any useful application to the relief of the Mississippi. The source of this bayou, which was closed up to assist the military defences in the last war with Great Britain, by extending the line of levees across it, is only about six miles above Plaquemine, a point where, as has been shown, great relief can be obtained at little cost, and without serious damage to property. The water which would be drawn through the Manchac would be discharged into Lake Maurepas, and ultimately into Lake Pontchartrain. The use of this channel involves, therefore, all the objections standing against an outlet at Bonnet Carré, and many others which do not appertain to that expedient. Indeed, the suggestion of an outlet at this place is entirely without practical value, and scarcely worthy of detailed discussion. The channel of the Manchac is long and narrow, and incapable of bearing a volume of water which could produce any appreciable effect on the floods of the Mississippi; and, if enlarged for that purpose, the cost of the work would be great, and the damage resulting from it excessive.

OF THE LA FOURCHE.

The bayou La Fourche is by far the least important of the outlets which have been left open, as a vent for the surplus or flood water of the Mississippi. This bayou gives passage, in extreme high water, to 10,200 cubic feet per second, or less than the one-hundredth part of the total high-water discharge of the river. Its descent near its source is only about three and a half inches per mile, which is but about the one-eighth part of the average slope of the Plaquemine as far as the Indian village. The velocity of the current is necessarily small, and it would not be practicable, therefore, to increase the capacity of the channel by the mere action of the water, if other considerations would justify the work.

But the extensive settlements on the banks of the La Fourche, offer a further and great impediment to the enlargement of its channel. The work would involve excessive cost, if viewed only in reference to the physical difficulties, and a great outlay also in compensation for damages to private property.

An inspection of this stream shows that the same necessity for protection is felt along its highly cultivated borders, as has been experienced in so

distressing a manner along the Mississippi itself. The bayou overflows its banks when the Mississippi is full, excepting as the water is confined by the artificial levees. But these levees have been very carelessly and slightly built; and are almost without exception of inadequate height and strength. When the Mississippi is in flood, the water along the bayou, for a great part of its course, stands within two or three inches of the level of the tops of the embankments. In many places, indeed, it is only retained within the levees by constant vigilance and labor. The embankments on which the planters here depend, are not as substantial as it is usual elsewhere to provide for a private mill-race; though the bayou is daily traversed by steamboats of five hundred or six hundred tons burden, which frequently push the water in a succession of waves over the levees into the adjacent fields.

These levees are generally from ten to twenty inches wide on top; from three to five feet high, and of very irregular slope,—each planter adopting that which his own judgment or fancy prescribes. When the water rises to the top of the levee, the proprietor commences driving pickets down into the face of the bank, behind which a board is planted edgeways, and kept steady and in its place by a few shovels-full of earth.

This frail bulwark, by constant attention, generally prevents the overflow; but when the river falls, these temporary fixtures tumble down, and are replaced again at the next high water.

To secure the property on this outlet from overflow in the present condition of things, requires a good guard levee, not less than six feet wide at top, with slopes of three to one or more; and set so far back that there may be ample space between the new and old banks to fill up with sediment, and thus strengthen the protection with age.

But it has been shown that the floods of the Mississippi are soon to be greatly increased, so that a much deeper column of water will enter the La Fourche at its source, and pass through it with a somewhat accelerated velocity. The present levees along the bayou are in very few places adequate to secure the plantations against the present floods, and they must disappear entirely before the wave that is to come.

It is recommended, therefore, to construct the guard levees, which it is here proposed to build, at least three feet higher than those now relied on, from Donaldsonville down to Napoleon; at or near this place to open an outlet into Lake Verret, to carry off the surplus there, and discharge it into Grand lake; and from Napoleonville to Thibodeaux, to bring the levee down to within a foot of its present height, by a gradual slope.

The fall from the top of the levee at Napoleon to Lake Verret, according to the survey of the State engineer in 1836, is twenty-two feet. The distance is seven miles and fifteen hundred and eighteen yards. In the first mile and a half the fall is seventeen feet, or at the rate of eleven and one-third feet per mile.

It would be extremely easy to create an outlet at this point of sufficient capacity to afford entire relief in high water to the whole country along the bayou. And, by cutting a canal from the lake up to a point within a mile of the La Fourche, and there constructing a lock, and an ample waste-weir, the same canal would serve to open a navigable steamboat passage from the Mississippi, by way of the La Fourche, to Lake Verret, and thence to Grand river, Grand lake and the Teche.

An effective outlet may also be made at Field's mill, by cutting a new

canal about one mile in length, or enlarging the old one leading into Field's lake, and thence through the bayous from Lake Long to the gulf.

Either of these outlets will afford abundant protection against the present floods, and greatly diminish the cost of the levees. But they cannot be made to produce any sensible effect on the height of the floods in the Mississippi.

The writer is aware that the construction of a guard levee along the La Fourche, to resist the weight of the increased future floods, will be regarded as at least premature, and perhaps entirely superfluous. He makes the suggestion, however, after sufficient reflection, and in the fullest confidence that these guard levees will be found necessary, without assuming any increase in the aggregate volume of water discharged by the Mississippi, whenever the embankments along the coast of Point Coupee and West Baton Rouge are made high enough and strong enough to bear the weight which now presses upon them, without giving the water vent through crevasses. If crevasses were prevented from relieving the channel of the Mississippi above Donaldsonville, there are no levees on the La Fourche that would not be at once overtopped by the present floods.

OF THE PREVENTION OF CUT-OFFS.

It has been shown that the consequence of cutting off the bends of the river, as has been effected on several occasions by design, and often in the past history of the Mississippi, by the unassisted action of the current, is to increase the height of the floods below, and to reduce them above the bend. It is therefore recommended that prompt measures be taken to prohibit all attempts to effect or encourage such cut-offs in future, as well as to guard against their occurrence from accidental causes. Such a course will, indeed, afford no relief from present suffering, but it will serve to protect the river coast against one prominent cause to which we may look for an increase of future local inundations.

There are many points on the river where the water is gradually encroaching upon the soil, and reducing the width of the narrow necks of land which now separate the channel above from that below the great bends of the river. It was not the province of the writer to engage in minute surveys of these places: but it was necessary to this report that he should ascertain whether the progress of the water upon the land at any of these points rendered immediate attention proper. With that view, levels were run across the narrow isthmuses, and other observations made, sufficient to enable him to judge of the probabilities of cut-offs having place at the several bends where they were thought to be most imminent. There were other bends which were not examined, though now deemed equally worthy of careful survey. The points to which attention was particularly directed were—

1. *The American bend*, which commences about ninety miles below the mouth of the Arkansas.

This bend was examined May 15, 1851. The distance across the neck, measured to the water on each side, was five thousand and sixty-nine feet. The distance around the bend is computed to be fourteen or fifteen miles; but it was not measured. The fall of the water, or difference between the surfaces, as found by levelling from shore to shore across the bend, was 3.68 feet.

The evidence is conclusive, that the narrow neck in this bend is wearing away very rapidly. About twenty or twenty-five years ago, the distance across, which is now less than one mile, was fully three miles. It is thought by the resident proprietors that a width of four hundred yards, or more, has been cut away on the upper side in the last two years. The river is still obviously wearing away the soil, and threatens to abrade it more rapidly hereafter, in consequence of a change in the shore above, which causes the water to impinge more violently upon the bank at the narrowest part of the bend.

The land is cleared entirely across the narrow neck; and in high floods the current sweeps over it, and the water is consequently discharged over the loose bank into the reach below, with a pitch of about two feet.

A cut-off is very likely to have place in this bend at some early day, unless proper measures be taken to arrest the progress of the current, which is now acting steadily upon the yielding soil. Should this be the result, there will be a local increase of eighteen or twenty inches in the height of the floods below the bend, at Worthington's landing, and thence down to Princeton, and not a great deal less at Lake Providence. Indeed, the effect will be sensibly felt as far as Vicksburg; and it will be found impracticable to protect the coast in all that space—from the foot of the American bend to Vicksburg—by the present levees. The consequences of a cut-off at this point will, in fact, be most disastrous. Some of the finest estates in upper Louisiana and in Mississippi will be inundated, or only preserved by the construction of an entirely new and costly line of levees.

In view of the serious consequences which must result from a breach through this narrow neck, it is the duty of the writer to recommend that an accurate survey be made promptly of the entire bend, and of the bend above, with a view so to change the course of the impinging current as to prevent the further progress of this abrasion, or to arrest it by works which shall be adequate to resist the river.

Provision should also be made to enter upon the undertaking as soon as these details are obtained, and the plan is decided on.

2d. *The Terrapin Neck bend* is at a point about thirty miles above Vicksburg. The distance across the bend was found by measurement to be only one thousand five hundred and eighty feet. The distance around is variously estimated at from twelve to twenty miles. The fall, from the surface above to the surface below the bend, is two feet.*

The river is constantly cutting this narrow neck away *on both sides*. It was not practicable, during the high water that prevailed at the time of the examination, to ascertain the character of the soil. But it was apparent that the caving now going on is very considerable on the upper side, for a space of more than two miles, and quite obvious also on the lower side.

A cut-off will be produced here, by the current itself, at an early day, even if the result should not be hastened by that portion of the public interested in its effects. But the river will not be permitted to work its own way. During the last winter a ditch about fifteen feet wide, and three feet deep, was cut across the neck, into which the water was admitted as the river rose. The current was strong, and the danger of an immediate cut-off was sufficient to attract the attention of the planters on the river below,

*As shown by the level, 1.96 foot; but allowing for the subsidence of the floods, it would be properly two feet.

who repaired to the spot with their forces, and arrested the water by throwing levees hastily across the ditch, and afterwards filling it up with trees and brushwood.

It would be charitable to suppose that the persons engaged in this work were ignorant of the mischief which it was likely to produce. It is scarcely to be assumed that any one who has witnessed the distress occasioned by the floods upon this river, would willingly inundate those beautiful plantations which are now only preserved by the slender protection afforded by the feeble barriers of the individual proprietors. This effort was probably prompted by ignorance; but ignorance may prompt it again, and there will be nothing to prevent a dozen misguided persons from inundating the whole coast for thirty miles above and forty or fifty miles below Vicksburg, by cutting a ditch here, which can be accomplished in a week.

It is important that this bend also should be promptly surveyed, and the most effectual measures taken to prevent the abrasion of the shores on both sides of the neck. It is not necessary, and it would scarcely be prudent, to make the survey one season and do the work the next. *There should be no delay here.* The survey will occupy but a month or six weeks in the fall; and the work, which is not difficult, should proceed immediately after that has been accomplished.

If a cut-off be permitted to take place at this point, the whole coast, on each side of the river, will be swept, as Point Coupee has already been, from Milliken's bend down to Grand Gulf. The effects will be less obvious below, but the difficulty of maintaining the levees will be sensibly increased as far as Natchez.

3. *The Vicksburg bend* is the next point, in descending the river, at which a cut-off seems likely to have place. The distance across the bend was found to be, from water to water, 7,712 feet. The distance around is estimated at ten miles. The fall, from the surface above to the surface below the bend, as the river stood at the time of the examination—about fifteen feet below the high water of 1850—was 2.25 feet.

Though the current here bears with great force against the bank on the upper side of the bend, it does not appear to be encroaching rapidly. Some work has been done on the neck, of which the object was represented to be to promote a cut-off; but it did not seem, as far as it had been carried out, that such was the actual purpose. Ditches have been commenced, but not extended entirely across the neck, and the timber that has been felled is left lying upon the ground.

A cut-off is not likely to occur here at any very early period, unless it be forced; and as one of the immediate effects of such an event would be to carry the navigable channel of the Mississippi several miles west of Vicksburg, leaving that town upon an inland lake, it is not at all likely to be accomplished by design, without meeting stern resistance from that place.

There does not appear to be any immediate danger of a cut-off at this point, yet such an event may occur in course of time, and it would therefore be wise to take efficient measures at some early day to protect the shore thoroughly, and to guard against the future chance by appropriate legislation.

4. *The Palmyra bend* is a point at which a cut-off is much more likely to occur than at the bend opposite Vicksburg. The distance across the neck is now only 4,218 feet, while the distance around is said to be twenty miles; and the fall, as ascertained on the 7th May, when the water was

eleven feet below the high water of 1850, from the surface above to the surface below the bend, 3.64 feet.

If nothing were done to promote the invasion of the river upon the bank at this point, a cut-off would probably not occur here at any very early period. But the narrow isthmus that now separates the two channels bears indubitable marks of a fixed intention to produce this calamity.

A ditch was formerly cut across the neck, but it was not made large enough to effect the purpose, and shrubs consequently took root and sprung up before a sufficient flood occurred to wash it out deeper and wider. Another, but a very clumsy effort, was again made during the last winter, by cutting off the timber, clearing out a portion of the old ditch, and commencing a new one: but it is said that the parties engaged in this mischievous work were deterred, for the time, by threats from below, and consequently failed to carry out their intentions. It is apprehended that those who have undertaken this labor will not wait for the slow progress of the river, but may renew their efforts on some future and more favorable occasion.

It is earnestly recommended that this bend also be promptly and carefully surveyed, and such works commenced as will be found effectual in changing the direction, or resisting the action, of the current.

It is also respectfully suggested that the great interests likely to be swept by the perpetration of the plans of those who are engaged in this wicked project, would justify, and seem to call for, some appropriate legislation to guard the country against such wanton injury.

If a cut-off should be made in this bend, the coast of Concordia, on the Louisiana side, and that of Claiborne, Jefferson, and Adams, in Mississippi, will be assailed by floods for which their present levees are wholly unequal. The mischief will be severely felt as far as Natchez; and the plantations thence to Red river will be deprived of much of the advantage which they acquired from the cut-off at Raccourci—a work that was made at the cost of many plantations on the coast of lower Louisiana.

The height of the floods will probably be increased by a cut-off at Palmyra bend, ten or twelve inches at Natchez, and nearly twice as much at Grand Gulf.

5. *The bend near Grand Gulf* is the only other point at which instrumental examinations of probable cut-offs were made, though there is reason to believe that there are several others which will demand early attention.

The distance across the bend, on the plantation of Colonel Coffee, when the measurements were made, (May 5, 1851,) was 3,907 feet. The distance around is said to be seven miles. The fall, from the surface above to the surface below the bend, when the river was 9.5 feet below the high-water line of 1850, was 1.1 foot; and during the high water of 1851, as determined from the tree marks, 1.3 foot.

The ground is gradually wearing away on both sides, and the distance across the neck is constantly, though slowly, diminishing. If the action of the river be not assisted by persons residing above, or others interested, there seems to be no immediate danger of a cut-off. But an effort has been made here, also, to assist the action of the river by clearing off the timber and cutting a very insufficient ditch. This effort may hereafter be repeated and more appropriate means adopted.

A cut-off at this point would increase the floods below from six to eight inches, and render the condition of many of the levees very precarious.

Other details of these examinations will be found in a supplemental re-

t. Cross-sections of the river were taken on both sides of each cut-off, ich show that the Mississippi is making constant progress at every one the bends enumerated, and will ultimately cut its way through the in-vening land, unless prevented by works adequate to change the direction its current.

It is not, however, the intention to urge a permanent resistance to the rking of the river. There are many reasons why these cut-offs should permitted, and even aided, if it were not that the country below them uld be deluged. In course of time, when the authorities in whom e control of the Mississippi is lawfully vested, shall have adopted ade-ate plans for the protection of the delta and the reduction of the floods, d adequate means are appropriated to carry them out, and the work has far progressed that an additional rise of two or three feet may be haz-led without apprehension, then, but not till then, it will be proper to cut the great bends of the river, and let the water rise below them. But is thing ought not to be permitted before competent means are provided protect the property below, or to compensate the sufferers below. othing can be more unjust than to inundate whole parishes, by disturbing e natural adjustment of the stream, and leave a sparse community to con-nd unaided with the evils recklessly or ignorantly poured upon them.

It would seem to be proper, in view of the great destruction of property hich may be produced by cutting off the bends between Red river and the rkansas, to provide for such attempts by appropriate legislation. This ight be the means of at least preventing the acceleration of the evil. To revent its occurrence from natural causes—by the slow and certain pro-ress of the current—efficient works should be commenced forthwith, to rotect the points assailed, by sheathing the shores, so that they will not ash away and cave in, or by changing the direction of the water, so that may cease to wear away the soil at the points of danger, and, instead, eposite material that will serve as a protection.

OF PROTECTION BY LEVEES.

The Mississippi river, it has been stated, is now confined and retained within its banks entirely by levees, extending along both shores for a space f nearly seven hundred miles of its course. These levees are private works, constructed and kept up almost altogether by the individual pro-rietors of the river front. The security of the country depends, therefore, n the vigilance, providence, good judgment and experience of perhaps ive thousand, and possibly ten thousand individuals. There are statutes, t is true, providing for the repair of these works when thought to be inse-ure, and supervisors, whose duty it is to inspect the embankments and en-force a proper care.

In case of the occurrence of a crevasse, or breach, in the levee, the water rushes over the cultivated soil, and fills up the swamps, until it is ultimately drained off by outlets leading into lakes, which communicate with the sea. The flow of the water is soon checked, on the up-stream side, by the gradual but general ascent of the country, which, it has been shown, dips from the north to south at the rate of eight inches per mile; and it is often arrested, in its course down stream, by the elevated borders of one of those ancient bayous which put out from the high banks of the Mississippi, as so

many ribs from the vertebral column, and officiate as *traverses* [illegible] to the country from the advancing overflow.

To an engineer, accustomed to the dimensions of a common canal bank and the extreme care usually bestowed on its form and in its construction it is a matter of some surprise to see what a slender bulwark men have ventured to place between the waters of the Mississippi and estates, of which the fertility is a proverb. It is indeed wonderful to observe the security with which the country trusts to the natural discipline under which the great river is expected to perform, each year, the precise movements of preceding years, and the surprise with which its occasional deviations are observed. The levees have, accordingly, been raised but ten or twelve inches above the known high-water marks, and are supposed, with such a margin to be tolerably secure.

In the sections below will be seen, side by side, a specimen of a Mississippi levee and that of a common canal bank; each intended to resist a pressure of six feet of water. (See Fig. 10.)

The width of the canal bank, it will be observed, is three or four times as great at top as that of the levee; it has a much greater margin above the surface of the water, and it is built with a column of impervious puddle, to connect the bank with the best soil below. But, after taking all these precautions, and constructing the work with a degree of attention unknown on the Mississippi, the prudent engineer takes care to provide each level of his canal with adequate *wastes*, over which an accidental surcharge of water may be shed. Yet with all these safeguards, and the exercise of habitual vigilance, breaches are not unfrequent occurrences on the best managed canals. On the Mississippi, the levees are rudely constructed, and generally by inexperienced persons, without the exercise of any of those prudent precautions which universal experience dictates. The river is nowhere provided with artificial vents, to let off an accidental surplus of water, and there is no general head to organize, discipline or control the supervision of the lines. All is left to chance, or to such superintendence as the parish authorities may prescribe.

The consequence of this state of things is, that whenever the river rises within one or two feet of the summit of the embankments, breaches begin to take place, and the water rushes through with great velocity, rapidly carrying off the light material of the levee, and widening out the open space, until it is arrested by the planters, or by a more substantial soil. But it is not to be supposed that it is only necessary to make the *present levees* stronger, and guard them better, to obviate the necessity, and entirely prevent such occurrences. No such precautions will be found to be sufficient. The most that can be expected from these embankments is to preserve the country against the effects of moderate floods, which do not reach their summit. But they cannot be depended upon to resist those greater floods which now so often deluge the estates along the coasts; for, if crevasses should not occur for the relief of the channel, the water would rise higher, and pour over the tops of the banks. In fact, the Mississippi is now only prevented from obtaining relief in that way by the outlets which its own power forces for the discharge of its surplus through the weaker points. Crevasses can only be prevented by this process, with the supply of water sent down during either of the three last years, by both greatly strengthening and greatly raising the levees. How high it would have been necessary to raise them, had no breaches occurred, from Lake Provi-

ce down to New Orleans, we have not the data to show with certainty. e volumes discharged through the crevasses above Red river have never n estimated. But we are assuredly on the side of moderation when we clude that if all the embankments had remained perfect, they would e needed an increased elevation, in many places, during the flood of this r, of *more than four feet*.

The protection of the coasts of the Mississippi, in lower Louisiana, inst such floods as now come down, involves no insuperable difficulty. guard levee, three feet higher than those now in use, with an occasional verse or lateral levee back to the swamps, and a moderate increase of capacity of the Plaquemine, are, in fact, all the expedients that need resorted to. To construct such a guard levee as this, from Red river to w Orleans, on both sides of the river, and down the Atchafalaya,—say a ee averaging eight feet high and 450 miles long,—would involve an exnditure of probably not more than $2,500,000. Such an expenditure uld, in fact, be ample to protect the whole coast below Red river from floods that are now felt. But such works would not protect the coun- above, and would be incompatible with the drainage and reclamation of delta.

But it is not the protection of the country bordering the Mississippi inst the present floods which constitutes the essential difficulty of this oblem. It is simply to provide adequately for the increasing artificial ods which are about to come, by which we are embarrassed.

It has been shown that the work of reclamation in upper Louisiana, Missippi, Arkansas and Missouri, will and ought to continue to go forward; d hence the works of protection for the country below must keep even ce with these. For this purpose it has been recommended to open exsive outlets at various points, to give vent to this water as it comes; and commence with the two, that leading into Lake Borgne and the enlargent of the Plaquemine, which can be most promptly brought into active d efficient service. The great outlet upon which we hope ultimately to ace much reliance, the Atchafalaya, it has been shown, cannot be made rviceable in time to relieve the Mississippi of the threatening deluge. It ll be recollected that we are to provide adequately for—

1. The floods which *now* injure and alarm the country. To make the ast below Red river tolerably secure against the present supply of water, e must keep the surface down at least twelve inches below its present gh-water marks.

2. To effect this we must provide vents for the water that is now disarged through crevasses. To dispose of this volume we must either ar levees, or make outlets, equal to the protection of the country against rise of four feet above the present high-water mark. This condition, we rely exclusively on levees, involves the entire reconstruction of all e embankments below Red river.

3. We must provide vents for, or protection against, the additional mass f water that is to be thrown into the channel as the cultivation of the ew States above progresses.

4. We must provide a vent for, or protection against, the greater volme of water to be poured down in a given time, in consequence of the xtension of the levees, and the exclusion of the floods from the natural eservoirs of the delta.

It is not the intention here, in dealing with such vast quantities, to

seek, or to profess to attain great accuracy. But it is the belief of writer, founded on the facts set forth in this paper, that to afford needful protection we must provide means adequate to give vent to, o resist, an increased discharge of at least 700,000 cubic feet per second, about seven-tenths of the present high-water discharge through the ch nel of the Mississippi.

In this view he has set no limit to the volume that shall be drawn by the outlet into Lake Borgne, but has recommended that the cut there boldly made; and that the river be allowed to take the pitch of ten fe and force its way through as deep and as wide a channel as its power produce.

If it can make an entire new channel, navigable for ships, through La Borgne, and tranfer its bars from the Balize to the deep water south Ship island, or produce a new one there, there let it go.

In this place, also, he has set no limit to the volume that shall be dra off by the Plaquemine, but proposes that that outlet shall be enlarg until its enlargement be found to produce damage to the interior nea equal to the advantage gained on the coast.

And in this view he proposes that the work on the Atchafalaya be co menced, though confident that the capacity of that bayou cannot be i creased fast enough to meet the emergency of the case.

But in addition to all this, the protection of lower Louisiana will requi other expedients. For this State, indeed, there is no alternative. Sl cannot wait for Congress to discuss, doubt, survey, and appropriate. Sl cannot wait for the slow machinery of legislation. She must build leve without hesitation or delay, or see her fields annually swept by the floods

It is not intended here to recommend any given height of levee as suf cient in itself to protect fully any part of Louisiana. A line of guar levees is proposed from Red river down to Plaquemine; and around Ol river, and down the east bank of the Atchafalaya, as the means of affordin the quickest protection against the floods as they are, or as they probabl will be when this levee is capable of retaining the crevasse water within th channel. But for those greater floods which are yet to come, this leve can only be regarded as an auxiliary protection, and a means of makin the enlarged outlets do a greater duty. To perform this part, and retai within the channel the water now discharged by crevasses, without the ai of outlets, this guard levee should be raised at least six feet above th highest known floods on the coast at the point where it is proposed to b built. It is indeed doubtful whether, from the best information that ca now be procured, a levee six feet higher than known floods would have been more than sufficient to guard the country below Red river securely against the flood of February, 1850, if no crevasse had that year occurred fo the relief of the Mississippi. The height of six feet is further proposed as a limit which it will be very difficult to exceed on the coasts above, and in the belief that after such a levee has been completed, outlets and other guards can be prepared soon enough to meet the increased discharge as fast, or faster, than the works above can be made secure to send it down.

Simultaneously, therefore, with the enlargement of the Plaquemine, and the opening of a new pass below New Orleans into Lake Borgne, it is pro-posed to commence a line of guard levees at the Raccourci cut-off, thrown entirely back of all the present private or public levees, and to be raised in no place less than six feet above the highest floods. The present levees

will serve in some degree to protect the strips of land lying between them and the guard levee. The guard levee will prevent the extension of overflows, and aid in reclaiming the swamps.

The cost of such a levee as is here proposed would be about $12,000 a mile. This will seem an extravagant sum, and doubtless something cheaper will first be attempted. But to construct a proper levee on both sides of the river, from New Orleans to the mouth of Red river, and on the west side around Old river, and a similar appropriate work down the Atchafalaya to the raft, will involve an outlay of at least $5,000,000. And in stating this, the writer wishes to express the further opinion, that if such a levee be now made it will not serve to protect the country below Red river ten years hence, unless it be aided by those other expedients which have been, and which remain yet to be recommended.

It may be well to suggest that it might be good economy so to lay out these guard levees that they may hereafter be used as the foundation of railway tracks, to accommodate that land now inundated, which a bold and sufficient course of improvement will bring under tillage.

These suggestions are intended to meet the present state of things in Louisiana below Red river. This is the part of the delta which is first entitled to relief. If the work of reclamation and protection be commenced above Red river, either by Louisiana or the United States government, the water there excluded from the swamps will be sent down to increase the existing distress, before the lower country is properly prepared to receive it.

If Congressional aid is to be extended to any portion of the delta, it is, beyond all question, clear that every consideration of justice, prudence and humanity points to its first application to the country from Red river to the sea. When efficient guard levees and ample outlets are there commenced, and the means for their completion provided, then, and not sooner, it will be advisable and safe to extend the works higher up the coast.

OF THE PLAN OF RESERVOIRS.

We have now investigated the plan of outlets, and have approximated to the utmost effects that can be anticipated in attempting to dispose of the surplus water of the Mississippi by that device. It has been shown that there are great obstacles in the way of obtaining adequate relief by this process, and that the amount of relief which is possible will be limited by the destruction that may be produced in the districts upon which the diverted flood will be thrown.

We have seen that, as the next most feasible mode of obtaining prompt protection, we must resort to a more efficient system of levees in combination with outlets; but that, after costly levees have been built in the rear of the present levees, and all the water that can be reasonably discharged by outlets has been drawn off through appropriate vents, these expedients must still be regarded as mere palliatives, limited in their application to the lower part of the delta—and even then only warding off and postponing for a season, results which they cannot permanently prevent.

It has been shown, further, that the prominent causes to which the great floods of the Mississippi are attributable, are rapidly increasing in their effects, and will continue to increase with the progress of population and improvement, and the increasing value of land: that these causes are to be found in the artificial drainage instituted by individual proprietors wherever

the soil is turned by the plough, or may be reclaimed by removing obstructions from the natural channels, and in the exclusion of the water from the great reservoirs provided by nature throughout the length and breadth of the delta.

The conclusion to which the mind is brought by a comprehensive view of this great subject is, that, after exhausting all other means which art supplies, for relief, it will be necessary, in order to assure the protection of the whole delta from overflow, compatibly with the reclamation of the swamps, to construct new reservoirs, in the hilly country, at the sources of the Mississippi and its tributaries: there to hold back a portion of the surplus water, and act as substitutes for those reservoirs which are thrown out of use in the low lands, by the innovations of society.

The vast importance of the subject must stand in justification of a further attempt—at the risk of some repetition—to explain the physical character of the delta, in reference to the applicability of this plan. A great plane, bounded on the east and west by hills several hundred feet high, slopes down from a point above the mouth of the Ohio to the Gulf of Mexico, dipping towards the gulf at the rate of eight inches per mile. The Mississippi flows down this plane in a trench averaging 100 feet deep; and pursues a course so serpentine as to increase the length of the stream to more than double the difference of latitude, and to reduce the slope of the surface to less than half the average slope of the plane.

At low water the surface of the river lies five or ten feet below the general level of the plane of the delta; at high water it attains a height of fifteen feet, and from that to twenty-five feet above the general level of this plane. As the river rises, it overflows its borders—which are elevated, by the deposite of previous overflows, nearly to the level of common high water—and of course, inundates the adjacent low lands to the depth of fifteen or twenty feet in the places where the depression is greatest. The deposites from overflow are greatest on the immediate borders of the stream, where the first precipitation occurs: and diminish gradually as we proceed from the channel into the swamps. A natural levee is thus formed by the material which is left on its borders by the stream when in flood. This levee is usually about thirty feet above the low-water level of the river, and slopes back until it meets the low level of the swamps, five or six miles distant.

The tributaries of the Mississippi, and those of its outlets, are formed in the same manner and present the same features as those which characterize the Mississippi itself. In low water they all lie below the general plane of the delta, and rise many feet above it when the river is high. They are all retained, excepting in times of great floods, between the levees which have been deposited by their own overflows.

The area lying between the Mississippi and the hills, and between the natural levees of the lateral streams, is an uneven plane, indented by alternate "sluys" and low ridges; which, with the exception of narrow belts of higher soil, are all subject to inundation when the river is above its banks. In the lowest depressions are found navigable lakes and bayous, and sometimes important streams, which serve to drain this water of overflow into the Mississippi as the surface of the river falls.

It will thus be perceived that the primary function of all that portion of the delta lying between the narrow strips of elevated soil which follow the windings of the streams, is to receive the water of overflow as the river rises, and thus mitigate the destructive effects of the flood. The whole of

this region, with the exception of these elevated belts, found chiefly along the immediate coast of the streams, is therefore to be regarded as a *natural reservoir*, formed to receive and retain for a season the surplus drainage of the Mississippi valley.

Recognising this fact, we are able to account for the anomaly which has already been noticed in describing this great river and its natural regimen. In passing from Memphis almost to the Gulf of Mexico, we find that the Mississippi maintains, with material local irregularities, about the same average width between its banks, and the same average area of water-way. It absorbs in succession the waters of the Ohio, the St. Francis, White river, and the Yazoo, and many other secondary streams, and yet appears to grow no larger, and flow no faster; it takes in the Arkansas and Red river, each rising in the Rocky mountains and flowing through a channel of fifteen hundred, or, as many suppose, two thousand miles in length, and it is no more formidable after, than it was before its column was swollen by these great contributions. The reason of this is, that the water of the Mississippi is drawn off by bayous, as the flood descends, and is discharged into the lateral reservoirs of the delta. The water that is poured into the channel by the Ohio, is partly drawn out by the reservoirs along the St. Francis; that which returns again into the channel at the mouth of the St. Francis, is taken up again by the swamps of the Yazoo; and that which is discharged by the Arkansas, is scarcely sufficient to supply the reservoir between the Mississippi and the Washita. The flood that comes from the Mississippi or Missouri parts with its water in passing from bayou to bayou, and is often entirely lost before it reaches Red river. *The swamps absorb it all.* A wave of fifteen or twenty feet at Memphis will scarcely be observable below Natchez, unless the rise continue for many days. The draught from the channel into the reservoirs reduces the volume flowing down the river in times of flood below Red river, to less than is found above the mouth of the Ohio.

Now we have seen how the planters who have established their homes along the narrow strips of fertile soil forming the borders of the lower Mississippi and its tributaries, have for years contrived to protect their estates from overflow by raising embankments near the edge of the streams, closing up the natural vents by which the water obtained access to these reservoirs, and confining it to its own proper channel. This water, unable to escape laterally, it is obvious, can only be discharged by rising higher and flowing faster. Thus it is that the portion of the floods which formerly filled these swamps or reservoirs for several months of almost every year, and then slowly drained off as the river fell—making a flood of more moderate height and greater duration—is now compressed between these levees or artificial dams, and can only find vent by rising upon itself. Each mile that is thus added to the length of the levees above, leads to the necessity of increasing the height of the levees below, or compels the planter to submit to a crevasse which shall sweep his own estate, and serve in some measure as a safety-valve to his more fortunate neighbor.

The effect of thus extending the levees has been fully discussed; and it has been shown that by the plans adopted, this extension is ruinous to the districts already leveed, yet necessary to the reclamation of the swamp lands, where the new levees are built, and therefore inevitable.

It will be readily admitted that the question how to reconcile these great objects, of protecting the cultivated fields of the States below, while redeem-

ing the swamps of the States above, involves some of the most formidable difficulties that can be encountered in the progress of useful improvement.

The physical difficulties alone, are of the highest order, and, as we have seen, must be boldly and promptly met, or the lower and most beautiful portions of Louisiana must be abandoned. But it involves other questions of serious magnitude, and covering other vast interests. It brings up grave questions of individual rights, judicial control and the rights of States. Viewing the immense stake at issue, or which at no distant day will be involved, it may be anticipated that if some adequate remedy be not provided, this question will ultimately lead to serious conflicts of interest.

If it be a maxim of civil law that men shall so use their own as not to do injury to their neighbors, the right of the counties above to interrupt the flow of water through its natural channels, and force it down upon the parishes below: or the right of Arkansas or Mississippi to reclaim their swamps by converting the sugar estates of Louisiana into a swamp; or the right of Missouri to drain her lakes by overflowing the cotton-fields of Mississippi and Arkansas—are questions which may yet become as difficult to the jurist and the statesman as the control of this great river is now to the engineer.

The subjects involved in this problem are too vast in their consequences to permit men to evade their contemplation, or to shrink from the efforts necessary to obviate the approaching events, or to mitigate the impending results.

Plans which, for ordinary purposes, it would be unsafe for a practical man to propose, and which, for ordinary purposes, it would be in vain to suggest, for an object of this scope, may well command attention.

Now, it has been clearly shown that the prominent cause of increasing inundations, and that which is still threatening greater evils, is the exclusion of the water of overflow from the swamps, and the destruction of the natural reservoirs of the Mississippi, by means of those embankments, originally commenced near New Orleans, and gradually extended up the coast. As the swamps are thus prevented from officiating as reservoirs, the river itself is converted into an artificial reservoir. The water that cannot get into the swamps must remain in the channel until it can traverse its length; and the embankments must be increased in height until the river is capable of holding the flood, or until the column acquires speed enough and depth enough to effect its own discharge. But the river is a reservoir of the most ineffectual character. To make it operative or reliable, either as a sufficient reservoir or conduit, more than 2,500 miles of continuous embankment must be reared and maintained on a caving and treacherous soil. More than one-half of this embankment has already been established, but not of sufficient dimensions to fulfil the purposes intended. The industry of individual proprietors, backed by the co-operation of counties, the liberality of States, and a vast donation by Congress, is now applied to the extension and completion of the line.

A bolder undertaking than that now contemplated has never engaged the thoughts, or been confronted by the courage, of any other people. It is even to be doubted whether it would be attempted here, with all the resources of the American character, and for all the inducements that stimulate the effort, if those now occupied with the work were fully aware of the magnitude of the labor, and of the future costs of re-construction and maintenance which it will involve. No safe conclusion can be drawn of the influence which the closing up of these open lines of levee will have upon

the floods, from any past visible results. The water, hitherto, has been but very imperfectly excluded from the swamps. It has found vent through wide spaces where there are yet no levees; through crevasses and abandoned lines. The present effort is to close up these gaps and make the lines continuous; but this, it will be found, can only be done after the old levees have been re-constructed on a broader base and raised higher.

The population—the sparse and by no means wealthy population—that has had the courage thus to face the Mississippi along its double front, and maintain their estates by damming the waters back, it is to be supposed will not be deterred from examining the project now suggested, of constructing dams upon the tributary streams which furnish this water, and substituting larger reservoirs in hilly districts, where the soil is valueless, for those which are destroyed in the rich bottoms of the delta. They who have already resisted the power of the river, where it has been necessary to construct dams along its whole course, on both shores, will assuredly be able to appreciate how much easier it will be to erect proper dams across the gorges of a mountain, where the reservoir is already formed, and bounded by high hills on every side, excepting the small gap to be closed up.

It is not the intention now, however, to discuss the proposition which the writer ventures to suggest, in detail. That has been done in another paper, which has failed to win the public approbation.* But it is his duty here to say again that it is entirely practicable, for a cost that will be fully justified by more than one of the great objects which will be accomplished by this plan, to hold in reservoirs surplus water enough to improve the navigation of every navigable stream in the Mississippi valley, by discharging the excess so retained, into the streams when it is needed there: and, at the same time, and by the same process, to protect the whole delta, and the borders of every stream in it, primary or tributary, from overflow.

But the writer wishes not to be misunderstood; it is far from his intention to limit exertions to the plan which he deems essential to full and permanent success. That plan will relieve, not merely the country below Red river, but the whole valley of the Mississippi, from the site of the reservoirs in the distant mountains, to the gulf. It will ultimately reclaim the swamps of the entire delta, and convert the most worthless and least habitable soil into the richest and most productive. It will render every stream that is ever navigable, permanently so. It will remove that great difficulty which men find in deciding on what rivers are worthy of national care, by rendering them *all* national. For, surely, whatever helps to protect the whole delta, in any degree, from overflow, and improves the navigation of the Ohio and Mississippi, must be considered of national importance—even though it may, incidentally, improve the navigation of the Alleghany and Illinois, so far as those streams are used as the conduits for the water.

Still, it is not the writer's intention to advise a dependence upon this plan alone, which has yet to pass through the slow ordeal of public investigation. On the contrary, he recommends a prompt and vigorous application of the power and resources of the proper authorities, whether national or local, to the preservation of the afflicted population of the delta, by all the means that have been discussed in this paper, and which may now be recapitulated.

1. By the immediate organization of a proper system for the construction

*See "Contributions to the Physical Geography of the United States, &c., by Charles Ellet, jr.," published in the 2d vol. of the Smithsonian Contributions to Knowledge.

and maintenance of the levees of lower Louisiana, under the direct authority and control of the State: that a new or guard line of levee be made—commencing at the mouth of Red river and extending down to the vicinity of Donaldsonville, about eighty miles above New Orleans, on both shores—of sufficient width at top for an ample roadway or railway track, and at least six feet above the highest flood which has been witnessed at the points where the levee is to be built.

2. That, simultaneously with the commencement of these improved levees, there be formed a new outlet from the Mississippi into Lake Borgne, about ten miles below New Orleans, to relieve the river at that point and reduce its level there as nearly as possible to the level of the gulf.

3. That, without any delay, measures be adopted to promote the enlargement of the Bayou Plaquemine, so as to relieve the river, in that neighborhood, of the increasing pressure of the floods which will be produced when the water which now escapes through the crevasses, is confined by the stronger levees recommended to be raised.

4. That, simultaneously with the formation of these safety-valves below, and the construction of a guard-levee, the necessary steps be taken to encourage the enlargement of the Atchafalaya, by clearing off and cultivating the borders, straightening the channel, and undermining the salient angles which it is desirable to remove.

5. But, while recommending these prompt and vigorous measures, it is the duty of the writer to express his conviction that, after all these means of relief, carried as far as prudence and a proper regard to economy and the interests upon which this excess of water will be turned, have been exhausted, they will be found insufficient to secure even the State of Louisiana against the floods which, at no distant day, will be poured down the Mississippi; while the great area subject to inundation, in Arkansas and Mississippi, can receive no sensible relief from any of *these* expedients but that of levees. To secure the whole delta, it will be necessary to commence promptly and press vigorously the great work of retaining the water in the mountains.

We come then to the question which is to be decided by the enterprising men and reflecting minds destined hereafter to cope with this vast subject. Shall the upper States go on to construct their levees, and raise them higher and higher as the water is found to rise in consequence of their construction—endeavoring to overcome by levees the difficulties mainly produced by levees—doing work, daily, which will inevitably lead to the immediate necessity of more work to render that work secure—or shall they begin to adopt, in connexion with that which produces so much incidental damage, a system of protection which, at every step, will do some good service to every interest? Shall it continue to be the policy, the favored and exclusive policy, to make whole provinces and counties depend for their salvation on the perfection of every part of several hundred miles of embankment; and to force every individual to seek to protect himself against the efforts of every interest above him? Shall this system continue until the artificial banks of the Mississippi shall vie in height with those of the Po, and the population in the low lands, behind the intrenchments, shall be in hourly dread of crevasses of which the force will then be irresistible? In short, shall the aid of Congress continue to be invoked, and the legislature of States to be directed, to the indefinite prosecution of a scheme which adds to the present distress at every step of its progress, when the same re-

sults may be ultimately obtained by a process which harmonizes every interest and does good to all: which will, at the same time, protect the entire coasts of the Mississippi, and the banks of its tributaries; reclaim the swamps of the whole delta, and improve the navigation of every river of which the floods are received by the Mississippi?

But it may be asked, where is this work to be commenced, and how is it to be prosecuted, to accomplish visible results over a field so immense, in any reasonable time? The public mind has yet to be convinced that it is even practicable to retain a sufficient volume of water in the mountains to reduce the floods in the Mississippi any sensible amount. It has, it may be added, yet even to be persuaded to reflect upon the practicability of the suggestion. In the view of those accustomed to advocate and conduct difficult enterprises, it is precisely the persuasion and conviction of the public mind of the feasibility of a measure, that constitutes its difficulty. When men reflect on any thing which has a solid basis of truth, they have arrived near the point of conviction.

It is not difficult to show that, to reduce the floods of the Mississippi one foot, we must draw off or retain in reservoirs about 20,000,000,000 cubic feet per week; and that to retain this volume will require a reservoir 110 feet deep and covering seven square miles. Consequently, it would not be difficult to show, that, to reduce the floods twelve inches for a space of sixty days, would require that nine such reservoirs should be applied to that purpose. It would not be difficult to show that these reservoirs would retain water enough to maintain the navigation of as many of the most valuable rivers that flow into the Mississippi from the east; but, to bring the proof in detail, will require surveys; and to obtain such surveys, will require the confidence, leisure, and action of Congress.

Until these surveys are ordered, the further discussion of this subject will be premature.

When the minds of men are directed to the fact, that the floods are increased by the destruction of the natural reservoirs of the delta, it will not, perhaps, be difficult for them to appreciate that they may also be reduced by the creation of artificial and better reservoirs to replace those that are destroyed.

Under the operation of the causes which have been explained, the course of nature has been disturbed, and floods once regarded as exceptions to the usual order of things, are now of almost annual occurrence.

Under the operation of human agency, and nothing else, the waters have been, and are still being diverted from their course, and concentrated in the great rivers; and it is now proposed to counteract the hurtful effects of this diversion, by works of art, calculated first to restore, and ultimately to improve, the natural regimen of the streams. It is proposed, in short, to construct new reservoirs to receive the increased drainage produced by the plough, and to compensate for those reservoirs which have been, and are about to be destroyed by the spade; to substitute for the swamps, which have always received the waters of overflow, capacious lakes in the rock-bound valleys of the Alleghany and Rocky mountains. It would seem to be useless to demonstrate that such reservoirs will be cheaper and more efficient than the reservoir which has been formed of the river itself, by the levees, and which can only be made secure by the maintenance of from two to three thousand miles of embankment on a soil always liable to slip and be undermined by the action of the pent up water.

In the view of the writer, every effort should be made, while new vents are being opened and guard levees constructed below, to retain the surplus water in the lakes at the sources of the Mississippi and Missouri, and along the course of Red river: while proper sites for reservoirs should be sought in all the appropriate valleys of the Alleghany, and ultimately those of the Rocky mountains. For this object, he respectfully recommends that surveys be promptly instituted at the sources of the Monongahela, Alleghany, Kanawha, Cumberland, and Tennessee, and other tributaries of the Ohio, for the purpose of ascertaining the most advantageous sites for great reservoirs that will discharge through their respective channels. That, in the selection of these sites, regard be had primarily to the supplying of the Ohio and the greatest of its navigable tributaries with water in the summer months—using the reservoirs for the double purpose of withholding the flood water from the Mississippi, when that river is overflowing its banks, and supplying the water so withheld, to the Ohio itself, and its navigable arms, when their navigation is impeded by droughts.

That these surveys be extended promptly to Red river and its tributaries, for the double purpose of applying the great lakes with which that valley abounds, to keeping back the floods from its suffering population, and relieving its summer navigation from obstruction, by allowing the surplus so retained, to pass down in the season of low water. The lakes in the valley of Red river may be turned to good account in the prosecution of this plan, and the valleys of its tributary streams are understood to afford remarkable opportunities for the creation of great artificial reservoirs. The flood of 1849, by the destruction of the cotton crop of Red river alone, was productive of damages to the amount of five or six millions of dollars,* while less than the half of this sum would probably have sufficed to create reservoirs sufficient for the permanent protection of all its valley, and the great relief of the Mississippi delta from the mouth of Red river to the sea.

That investigations for the same object should be extended speedily to the Illinois, the Washita, and the Arkansas.

It is recommended that attention be first given to the control of the great navigable tributaries which pass through the most highly cultivated portions of the valley of the Mississippi—because on these a double service can be performed—the navigation can be improved while the floods are arrested. But, it is to be recollected that while this motive prompts us to look to the distant arms, it is those streams which, like the Washita and the Cumberland, discharge nearest to the point of suffering, that add most injuriously to the height of the floods of the Mississippi.

In closing his duties, the writer will venture to add a few suggestions touching the improvement of the navigation of the western rivers, which is necessarily embraced in this plan of restraining the floods. To produce useful effects, it is indispensable that the United States government, or all the States in the valley of the Mississippi, enter at once upon a general system of river improvement. Snag-boats must be put at work upon portions of the Mississippi, and all its navigable tributaries, in low water, to prepare their channels for the reception of a permanent supply.

Reservoirs must be constructed wherever it is practicable to find appropriate sites, and the commerce justifies the cost, large enough to receive

* This flood is represented to have produced a total destruction in the valley of Red river alone, of fully $7,000,000.

and retain the flood-water of such tributaries, and let it off again when the supply is needed for the navigation. It is not at all necessary to keep watch upon the reservoirs to see that they perform properly. It is perfectly practicable so to adjust their apertures that they may discharge constantly and almost uniformly; filling up when the flood comes down, and the supply is in excess, and falling again when the sources of the flood begin to fail. The system, when fully carried out, will be almost self-regulating. While the snag-boats are at work preparing the channels of the great tributaries, and the reservoirs are in progress of construction on the smaller sources, the outlets should be in process of preparation to the gulf, and the guard levees should be advancing below Red river. All these works will be necessary; and it is believed that by a general, prompt, and confident effort, directed simultaneously to the acceleration of the discharge of the waters below, and to their retention in reservoirs above, while strengthening the barriers on the lower coast, the works may at least keep pace with the progress of those causes which threaten the ultimate destruction of the whole of lower Louisiana.

It is impressed upon the mind of the writer with the force of demonstration, that these several measures must be adopted, and adopted promptly, or that causes now in operation will speedily bring great distress throughout the delta of the Mississippi, from the mouth of the Ohio to the Gulf of Mexico.

If they are adopted, this fertile country will prosper, and add vastly to the glory and wealth of the nation: if they are neglected, the population of the valley of the lower Mississippi must maintain a very long, though in the end, perhaps, a successful struggle against the increasing floods.

The position of Louisiana, in this eventful issue, is one of peculiar difficulty, and may result in inestimable distress, if she be left single-handed to struggle with the torrent which the industry and enterprise of the people of the upper States may pour down upon her devoted soil. However unequal and oppressive may be the contest, she can afford to lose no time, but must commence at once, whether aided or alone, to protect herself by outlets near the gulf, and by the most efficient levees near Red river; levees to prevent the deluge from sweeping over her surface, and outlets to vent the water more freely as it comes. Her fate is on this issue, and she is destined to bloom, the garden spot of this great valley, if her skill, finances and fortitude prevail, or to be known only as a desolate swamp if she falter and yield to the force of the flood. The question, whether she shall be allowed to stand alone, and protect herself unaided, from the difficulties forced upon her by the States above, or be sustained by that government which represents the power of all the States, is one of deep interest, which must be decided by the Justice and Humanity of the nation.

[The writer takes this occasion to acknowledge the valuable services rendered in this investigation, by his intelligent and careful principal assistant, Mr. I. Dickinson, who personally took, or superintended the taking of, nearly all the soundings and other measurements recorded in this paper.]

NOTES.

Note A.

It is not deemed necessary to burden this report with the details of the observations on the relative velocities of the currents at and beneath the surface. The results are correctly stated in the text, and show conclusively that no error of any practical value can be committed by computing the discharge of the Mississippi from the surface velocities; though great errors might be made by relying on the speed of the central currents.

The details of the observations upon which the writer's conclusions are founded, will be given in a supplemental report.

Note B.

The statement here given of the discharge of the Mississippi at Memphis, as deduced from the observations of Mr. Marr, needs special explanation. The average daily discharge, as it is given in Mr. Marr's report, for nine days of extreme high water, was

74,530,955,174 cubic feet:

or, at the rate of

862,626 cubic feet per second.

But, in the calculations from which this result is obtained, an allowance of a fraction over ten per cent. was made for an assumed retardation of the water beneath the surface.

The experiments of the writer not having authorized such an allowance, the ten per cent. so deducted has been restored, in order to obtain the result of the measurements at Memphis, when calculated in the mode adopted in this paper:—from the surface velocities.

Some of the observations of Mr. Marr show a discharge at Memphis in 1850 of 1,040,000 cubic feet per second, when no deduction is made on account of the supposed average retardation of the mass of water beneath the surface.

Note C.

It was the intention of the writer to discuss this formula, in some detail, in a note to the text. But being under the necessity of submitting this report hastily, and wishing to test the formula on shallow mountain streams, he is compelled to reserve this discussion, which will form part of a supplemental paper.

Note D.

The level of low water in the Ohio river, at Cincinnati, is 432 feet above tide. The surface of Lake Erie is 565 feet above tide.

By the recent survey of the Ohio and Mississippi railroad by Mr. E. Gest, civil engineer, the level of low water in the Mississippi at St. Louis is

ascertained to be 146½ feet below Lake Erie; Hence, low water in the Mississippi, at St. Louis, is 418½ feet above tide.

The level of low water in the Mississippi at the mouth of the Ohio, as ascertained by Mr. John Childs, engineer of the Mobile and Ohio railroad, is 275 feet above tide: whence the fall of the Mississippi, from St. Louis to the mouth of the Ohio, is 143½ feet, or, assuming the distance to be 200 miles, at the rate of 8½ inches per mile.

There is certainly no conclusive reason for questioning the correctness of this result. But the descent of the Mississippi above the mouth of the Ohio, which it exhibits, is so much greater than appears probable, that the writer is almost compelled to suspect some error in the determination of the height of low water at St. Louis.

Note E.

The following passage in the report already noticed, of passed midshipman Robt. A. Marr, deserves attention:

"It has been estimated that of the rain-water falling in the valley of the Mississippi, only $\frac{1}{1200}$ part reaches the gulf. What proportion is lost after once getting into the channel, is, I believe, not known. Between Memphis and Vidalia, there are immense tracts of overflowed land: and according to the above hypothesis, immense quantities of water may be taken up by evaporation and wafted by the winds, to swell the currents of far distant rivers: may disappear through the fissures in the bed of the Mississippi itself, or be absorbed and filter through the overflowed earth to fill the capacious chambers of subterranean reservoirs."

No authority is given in the report for this extraordinary estimate, which it is proper to say, is altogether erroneous. The discharge through the channel below Red river, *in a single day*, is about ten times as great as the above estimate for the whole year. The fraction $\frac{1}{1200}$ should have been about the $\frac{1}{3}$th: its *precise* value not having yet been ascertained.

Note F.

The following speculations concerning the future progress of the population of this continent, are found in the Encyclopædia Britannica—article "America:"

"We know with certainty that a prosperous community, possessing abundance of unoccupied land, will double its numbers in 25 years, *without any aid from emigration:* and as the scale ascends in geometrical ratio, a short time necessarily produces a wonderful change. It is to be observed, however, that the whites, possessing the advantage of superior industry, order and forethought, naturally increase faster than the other classes. In the United States this part of the population increases at the rate of three per centum per annum."

In this article the white population of the American continent is assumed to have been 21,000,000 in 1830, and to increase at the rate of three per cent. per annum; from which data the following results are obtained:

Number of whites in	1830	21,000,000
" "	1855	42,000,000
" "	1880	84,000,000
" "	1905	168,000,000
" "	1930	336,000,000

These speculations are carried still further in the article quoted. But they do not include the great element of all such computations when applied to the United States—the accessions to the population of this country from foreign emigration.

The above results, however, are sufficient to lead the reflecting mind to a safe conclusion on the question, Whether the delta of the Mississippi is or is not to be wholly reclaimed and brought under cultivation?

Note G.

The following is the table computed by Professor Riddell, for the height to which given volumes of water admitted into the upper end of Lake Pontchartrain would raise the surface of the eastern part of the lake. [Report of Joint Committee on Levees.]

Cubic feet of water discharged per second.	Corresponding elevation of the lake in feet and decimals.
46,756	0.027
93,513	0.111
140,269	0.250
187,026	0.444
233,782	0.694
280,539	1.000
327,295	1.361
374,052	1.777
420,808	2.250
467,564	2.777
514,320	3.361
561,078	4.000
607,834	4.694

This table may be used as a numerical approximation to the law by which the height of the lake, above a stationary or tideless sea, must increase, in order to force given volumes of water through the passes; but not as any approximation to the practical effect which a given volume, admitted into the lake, would have in elevating its surface.

Levée
High Water
MISSISSIPPI
Low Water
Levée
236 Miles
17.6
LAKE PONCHARTRAIN

Bayou
17.7
Bayou
Bayou
Bayou
9.7
6.9
Levee
High Water
MISSISSIPPI R.
Low Water
Levee

DIAGRA

showing the relat

of Floods in

MISSISSIPP

for several years at s

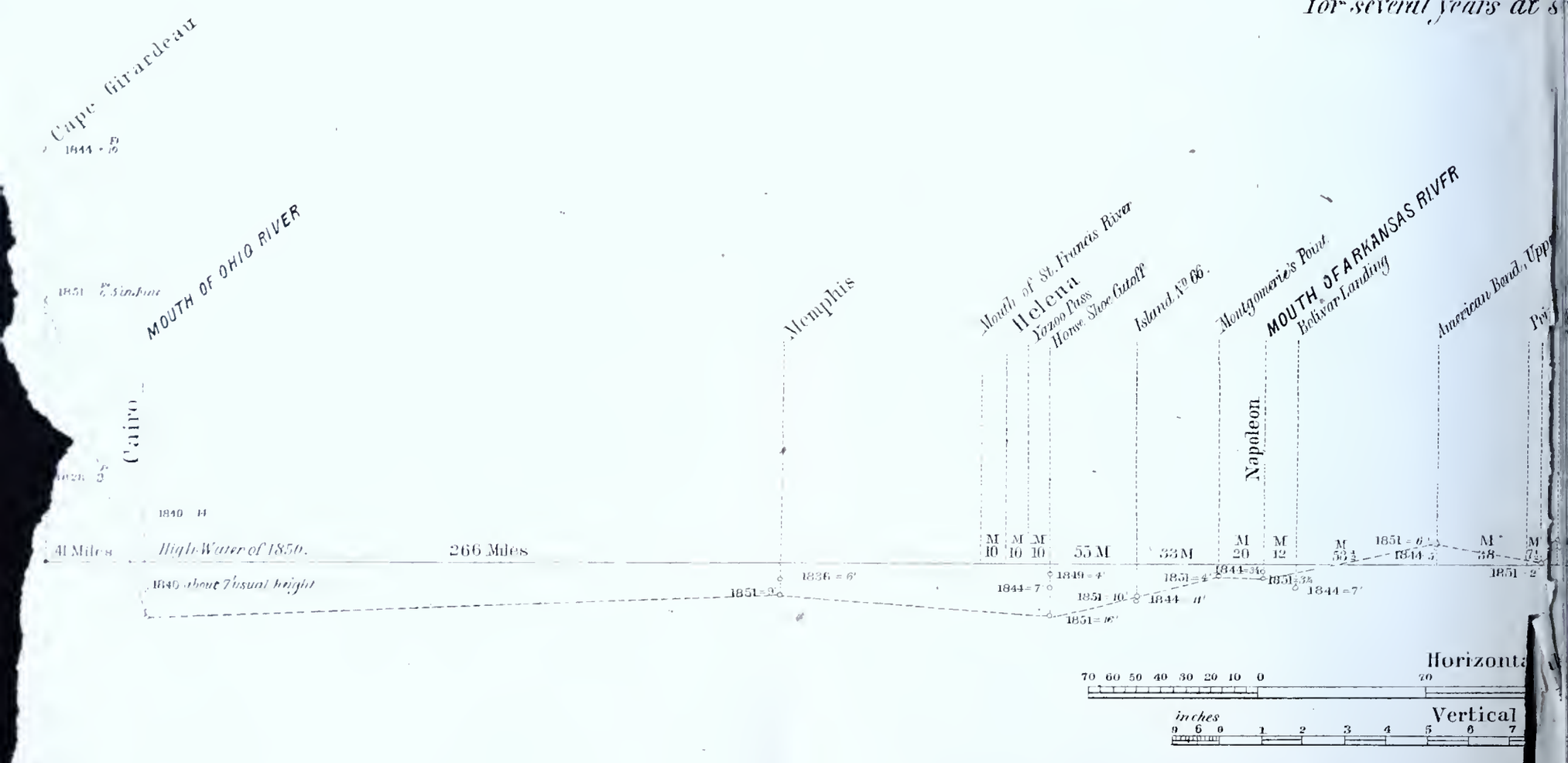

Fig. 8.

M

e heights

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RIVER

ral places.

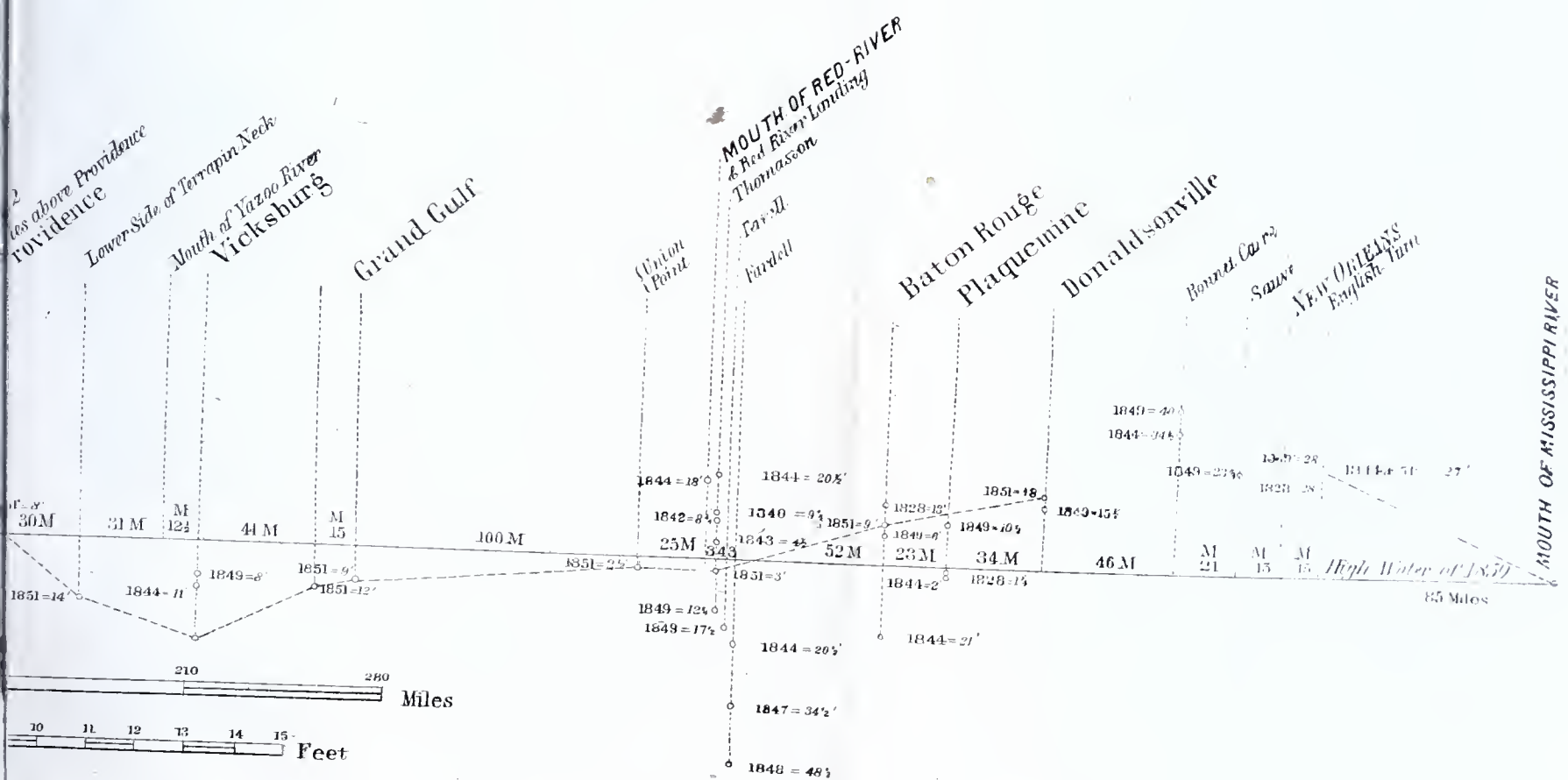
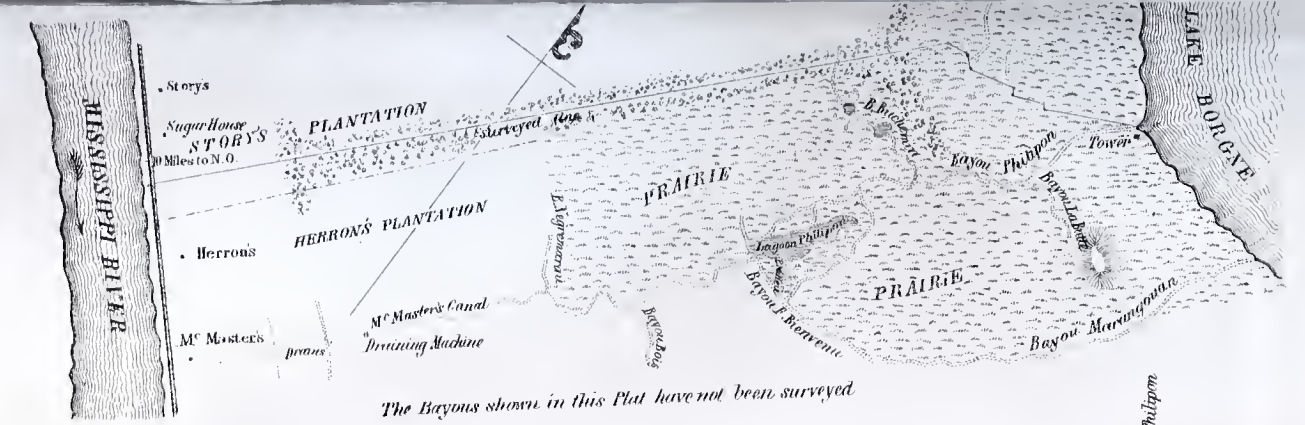


Fig. 9.


MISSISSIPPI RIVER
Storys
Sugar House
STORY'S PLANTATION
10 Miles to N.O.
Surveyed line
HERRON'S PLANTATION
Herrons
Mc Masters
Mc Masters Canal
Dredging Machine
PRAIRIE
Lagoon Philippon
Bayou Philippon
Tower
LAKE BORGNE
Bayou Marengouin
The Bayous shown in this Plat have not been surveyed

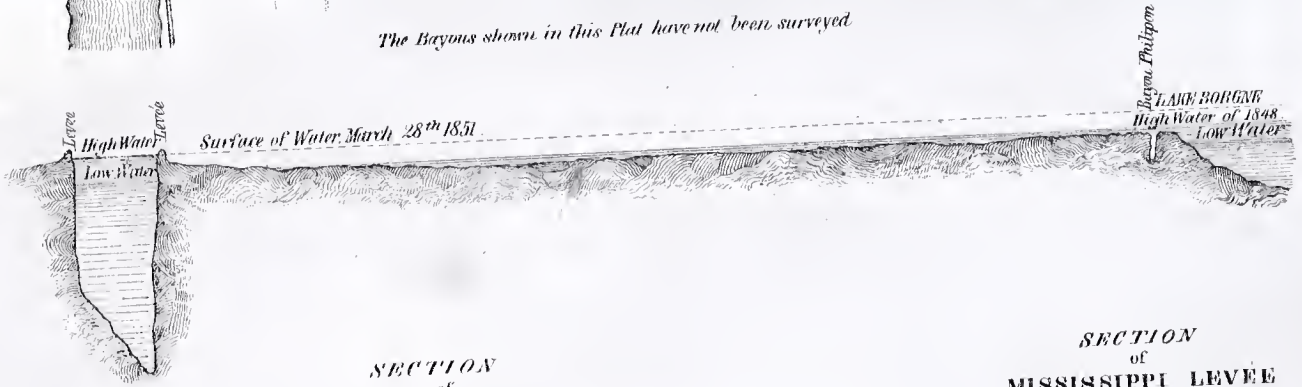
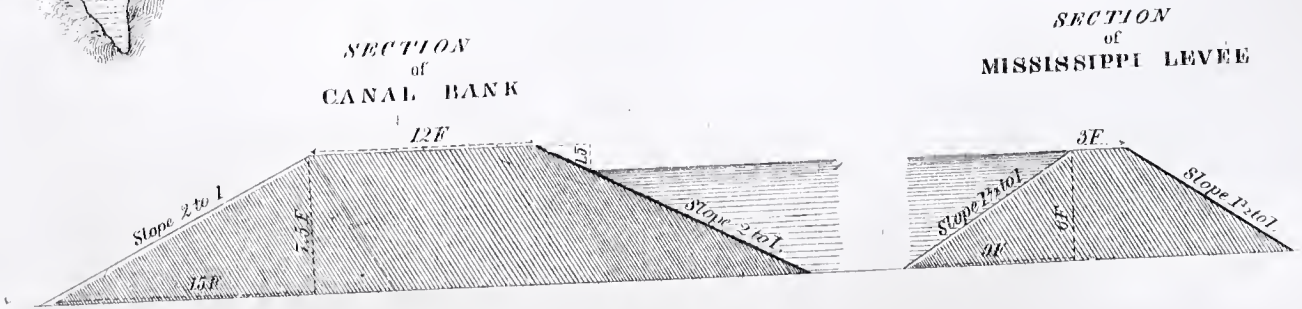

Levee
High Water
Low Water
Surface of Water March 28th 1851
Bayou Philippon
LAKE BORGNE
High Water of 1848
Low Water

Fig. 10.


SECTION
of
CANAL BANK
12F
Slope 2 to 1
Slope 2 to 1
15F
15F
SECTION
of
MISSISSIPPI LEVEE
3F
Slope 2 to 1
Slope 2 to 1
9F
9F