

survey of the portion of the river below Sacramento. The existing appropriation of \$20,000 will be expended as hereafter stated in this report.

#### OPERATIONS OF THE PAST YEAR.

Pursuant to advertisement bids for the removal of snags in the Sacramento and Feather Rivers were opened on August 1, 1878. No bids were received for the Feather River, and two for the Sacramento. The lower of these bids was accepted, and a contract was at once made with the bidder, Albert Foster, of Sacramento, for the removal of snags in the Sacramento.

The work was begun immediately, and by the close of the month 137 snags had been removed, which was all that seemed to be required at that time to give good navigation as far up as Colby's Landing, the present head of navigation. The test of the channel thus improved was made by passing through it boats with wheat barges in tow.

Later, about the middle of September, the water having fallen, a barge struck at Sherman Bend, not far above Colusa. The contractor was required to go over the river again and remove such snags as were dangerous in the lower stage of water. He removed, during September, 17 snags, making a total for the year of 154 snags.

Afterwards a few more snags had to be extracted, but not being done in presence of or by direction of the inspector they were not paid for.

Failing to get bids by public advertisement for removing snags in the Feather, the offer of J. R. Rideout for \$60 per snag was accepted. He began work on the 24th August, and by the end of September removed 9 snags below Marysville. Later in the season the same party found it necessary to remove other snags in order to maintain a good channel, but for these no payment was made.

#### SURVEY OF THE LOWER SACRAMENTO RIVER.

The legislature of California, at its session of 1877-78, created the office of State engineer, and made it a part of his duty to investigate the condition of the rivers of the State. At the same session a separate act was passed authorizing a survey for the purpose of determining the cost and feasibility of a relief canal which, tapping the river on its west bank about 35 miles above the city of Sacramento, should carry a portion of the flood waters and discharge them into Suisun Bay.

The United States having in view the improvement of navigation, the objects of all parties concerned could evidently be best secured at a minimum cost by co-operation.

Mr. W. H. Hall, civil engineer, was appointed State engineer, and Isaac W. Smith, civil engineer, was the engineer of the canal project.

The latter carried a survey by transit and level from Gray's Bend, on the Sacramento, a few miles above the mouth of the Feather, to Rio Vista, leaving stations along the bank. Rio Vista is about 15 miles above the mouth of the Sacramento. This latter portion of the line was run by a party under the direction of the State engineer, who also carried the line up Old River, and along Three and Seven Mile Sloughs. The State engineer also checked the levels made by Mr. Smith's party.

The work done by the United States was mainly hydrographic. Taking the outlines of the banks as established by the State authorities, the United States caused the bed of the river and of its subsidiary channels, of which there are a number, to be carefully sounded, the shape

and formation of the bars to be determined, and a number of sections of the channels to be made.

In addition, the party under Mr. L. J. Le Conte, who was the assistant in charge of our survey, made an instrumental survey of Georgiana Slough, which is an important subsidiary channel 12 miles in length, connecting the Sacramento and San Joaquin Rivers.

A less careful survey—rather a reconnaissance than a survey—was made of Cache Slough, a wide arm of the river which joins it on the west side just above Rio Vista. This arm is about 25 miles in length.

The length of channel comprised in these operations is 120½ miles. The number of soundings was about 85,000, over 4,729 lines. The shoals known as Heacock's, Hogsback, Ironhouse, and the one at the mouth of the river were examined with care, and their characters determined by 100 borings which supplied samples of the bottom.

These operations took place between the 11th October, 1878, and the 22d January, 1879, the early part of the winter turning out to be very favorable for field work.

The results of this work have been recorded on maps to the scale of 1 inch to 300 feet, with the necessary cross-sections and profiles.

The lower part of the river is visited by the tide, which rises as much as 6 feet at the mouth, becoming insensible at Sacramento.

The base of levels for the reduction of soundings in the lower part of the river was determined by the State engineer, who established a self-registering tide-gauge at New York Landing, on the San Joaquin River, just opposite to the mouth of the Sacramento. Other permanent gauges were established at Rio Vista, 15 miles above the mouth, and at Courtland, which is some 30 miles below Sacramento.

A local staff was established and observed close to the locality where soundings were made, and shifted from day to day. All of these gauges being connected by a line of levels, they afforded the means of determining the slope of the river, and a basis for the correction of soundings, which were reduced to the low-water stage of the river for 1878, at low tide. At the city of Sacramento a staff known as the 1849 gauge, which means that the zero of the staff is placed at the low-water of 1849, has been observed daily for a number of years. This staff afforded the means of establishing the level of the upper terminus of the river profile, and for the reduction of soundings in the vicinity of Sacramento.

In order to have a full investigation of the physical condition of the river, there remains yet unmentioned these points, namely, the discharges and the amount of earthy matter which is carried at different stages of water. These points have been the subject of a long and careful investigation by the State engineer, who has not yet reached his results.

A few observations on the sediment carried by the river were made during the winter by Mr. Le Conte, which will be noted elsewhere.

#### EXAMINATION OF RIVER IN A HIGH STAGE.

After the field-work of the survey had closed, severe rains prevailed; and, in consequence, the river rose to a moderately high stage and remained in this condition for some time. During this period an attempt was made to determine the movement of the bed of the river, which is quite unstable from the fact that it is composed of the mining detritus, chiefly sand. It is known that when the river is as much as 15 feet above the low stage, boats drawing 6 or 7 feet of water get aground.

This vertical movement of the bottom is both interesting and import-

ant, as is the whole subject of the movement of the great quantity of earthy matter with which the river is habitually loaded.

This study by Mr. Le Conte lasted a week, during which time the river raised from 10 to 12 feet above low-water mark. The information which it was possible to obtain with the facilities available is quite fragmentary, but it is also quite interesting and suggestive. It will be found as an appendix to this report.

The results of the investigation of sediment in the river are given in the following statement:

Place of observation, at the head of Steamboat Slough.  
Depth of water, 24 feet.  
Surface velocity, 5.72 feet per second.  
Velocity at 18 feet depth, 5.09 feet per second.  
Stage of the river, 10.85 feet above low-water.

Each sample was a mean of twenty, taken at the respective depths given in the table.

Sample.	Quantity of water.		Quantity of sediment.		Proportion and weights of water and sediment.	Remarks.
	Depth.					
	Feet.	Drachms.	Grains.	Grains.		
1	0	6.67	1.75	2,419.0	$\frac{1}{121}$	Very fine silt.
2	5	8.00	2.00	2,401.9	$\frac{1}{123}$	Fine silt with trace of sand.
3	10	6.50	2.25	3,317.7	$\frac{1}{133}$	Sandy silt.
4	15	9.75	4.75	4,665.6	$\frac{1}{147}$	Forty per cent. sand.
5	23	45.00	11.50	2,453.7	$\frac{1}{175}$	Clean sand.

#### RESULT OF SURVEY.

At the same time that the field-work on the Sacramento River was in progress a resurvey of the channels of Suisun Bay was made by a coast survey party under the direction of Assistant Bradford.

We have, therefore, as the result of all the operations that have been alluded to, a continuous record of the condition of the channels from Sacramento to the Straits of Carquinez, as they existed at the close of the year 1878.

As far as the river is concerned, the want of a full record of its condition 30 years ago, before mining had been begun, is now keenly felt. It is true that we have the published chart of the reconnaissance made by the exploring expedition under Captain Wilkes in 1841, but while this chart is of value for general purposes of comparison, it yet fails to supply the information in kind and extent that is desirable.

For future purposes of comparison we may hope that the results of the work of all the parties engaged on the survey during the past year will be found of great value.

When all the information that has been obtained shall be digested it is to be hoped that it will be an useful and instructive contribution to the physics of rivers.

Some time during the coming year it may be possible to make a report to the department which shall comprise the results of the investigations that have been made by the United States and by the State.

In the mean time, it may be said that indications point unmistakably to the conclusion that the bed of the river has as a whole risen in the past 30 years, and that the low-water slope of the river has been increased.

As a consequence, the effect of the tide has become less and less, so

that now it can scarcely be noticed at Sacramento, where the rise is said to have been quite 2 feet in 1849. The tide is now hardly felt above Heacock's Shoals, which is about 9 miles below Sacramento. The history of the gaugereading of low-water on the 1849 gauge at Sacramento, as shown by the following statement, justifies this conclusion:

The average reading of low-water on the gauge for the five years beginning with 1849 was 8 inches; for the next five years 14 inches; and for the last five years, 64 inches.

The low-water level of 1878 at Sacramento is 9.35' above the low-tide base established at New York landing. The low-water of 1849 was 3.85' feet above the same base.

The average depth of the river is shown by comparison with Wilkes's chart to be much less than it was 40 years ago. The testimony of all persons who have been long familiar with the river is to the same effect.

The effective depth for purposes of navigation, which is the minimum depth on the shoal reaches, has also been lessened, but not to the same degree as the average depth has been affected.

The annexed diagram, which shows the profiles of the bottom of the channel of Steamboat Slough, one of the arms of the river, as determined by our recent survey, and as plotted from the published chart of the exploring expedition, illustrates the changes just mentioned.

The small number of determined points in the Wilkes profile, and our want of positive information as to the base of reduction of the soundings of this survey, make the comparison of value only in a general way.

The peculiar and distinguishing influences to which the river is subject, by reason of the discharge into its tributaries of large quantities of detritus from the hydraulic mines of the State, have been referred to in previous reports. We may, with our present information, feel sure that the unfavorable changes which have been noted are directly connected with these influences. When we undertake by engineering constructions to restore, as nearly as may be the conditions that existed thirty years ago, re-establishing the low-water slope of that epoch so as to permit the tide to ebb and flow as far as Sacramento, and in this way restore a good channel, the immense quantity of movable material that encumbers the channels becomes a serious embarrassment to any system of improvement.

#### EFFECTIVE DEPTH FOR NAVIGATION IN THE LOWER RIVER.

The total distance from Sacramento to the mouth of the river is, by one route, 54 miles, and by another, 60 miles. About 30 miles below Sacramento the river is divided into two channels, known as Old River and Steamboat Slough. These channels reunite below Steamboat Slough, being a trifle less than 12 miles in length, while Old River, which is the eastern of the two channels, is 18 miles in length. During the whole history of navigation up to the past year Steamboat Slough has been preferred as a channel for two good reasons, namely, that it was both shorter and deeper. It is now, however, no longer deeper, having been very much choked by deposits during the past few years. The boats trading between this city and Sacramento, particularly those having any considerable draught of water, now, as a rule, go by Old River. The state of Steamboat Slough is illustrated by the longitudinal profile that has already been referred to.

Taking Old River as the future navigable route, we find by the last survey that 8 feet of water at low-stage of river and tide can be carried from Sacramento to the mouth, with the exceptions now to be noted.

The shoals are first Heacock's, in the main river 9 miles below Sacramento. Here there is only 6 feet of water and very little rise by tide. The length of this shoal is 2,000 feet. The next shoal going down stream is the Ironhouse Shoal, which gives only 7 feet of water for a distance of 4,000 feet. Next below are the Ida Shoals, one near each end of an island of that name. There is a channel here of only 7 feet for a distance of 2,700 feet, at the head of the island, and for a distance of 1,700 feet at the foot of the island. The tide visits both the Ironhouse and Ida Shoals and twice in 24 hours increases the depth to a maximum of several feet.

The loci of the shoals are similar.

In the neighborhood of Heacock's, where the width of the low-water channel does not exceed 600 feet, there is a fair channel of quite 8 feet depth. At the shoal the width of the river is about 900 feet. At Ida Island the river has two channels separated by the island. The narrower of these channels is 200 feet in width. At the Ironhouse Shoal the river is as much as 650 feet in width. A width of about 400 feet gives sufficient water.

The constructions that will be required to improve these shoals are first for Heacock's, a low bank of brush and stone, most of it built in water of 2 feet in depth, a portion in deeper water. The length of this construction with its connections with the shore will be 2,500 feet. At Ironhouse Shoal a wing-dam of 300 feet will be required, and at Ida Island the closure of the minor channel needs a dam 200 feet in length.

The estimated cost of these improvements is \$25,000.

#### THE REQUIREMENTS OF THE UPPER RIVER.

Going up from Sacramento 25 miles bring us to the mouth of the Feather, through which the great mass of the mining detritus reaches the Sacramento. We have no survey of this portion of the river. It is however known to be more or less obstructed by shoals, which, however, as far as is known, do not interfere materially with the navigation by the class of boats that are here used.

There seems, therefore, to be no present necessity of improving the channel along this reach. The same is true with some qualifications of the next reach in the river, extending nearly as far as Colusa, for a distance of 60 miles from the mouth of the Feather. The channel throughout this whole distance is believed to be good. No survey has been made of it, but no complaints are known to have been made of the existence of shoals that interfere with navigation. There are, however, some snags, but not nearly so many as exist above Colusa.

This reach of 60 miles is characterized by good banks which are not destroyed during freshets, so that there is something like a permanent condition of stability in the channel.

We, however, enter here just below Colusa on a change of conditions. From this point and for a distance of 60 miles, going upstream, we find on each side of the river, extending in a northerly direction nearly parallel, and distant from each other from something less than a mile to something more than 2 miles, a line of hard, permanent bank. The river touches these lines here and there, never both at the same place, and sometimes skirts on the banks for a mile or so, leaving it to pursue a tortuous course striking one or the other bank one or several miles below.

Where the hard-pan bank, as it is usually called, touches the river, the site is permanent, and all the villages and landings are found at

such points. Between these points of contact the river runs riot through a sandy bottom deposited by itself. If these hard-pan banks were 600 feet or so apart, instead of being in some places 2 miles apart, we would have a naturally permanent channel, or at least one easily regulated.

As it is now, when the river shifts its bed it undermines the bank and furnishes a yearly supply of oak and sycamore snags, which obstruct the channel and make it dangerous for navigation.

It is an obvious necessity to remove these snags. All the expenditure that has been made for the improvement of navigation has been directed to this object. This work has always been done by contract, and only so much has been done as appeared to be absolutely indispensable for safe navigation. A narrow channel has been kept reasonably clear of snags, but no attempt has been made to clear the river as a whole. The small amount of money available for the purpose has forbidden any attempt at thorough treatment. For the same reason, the necessity for economy, it has not yet been practicable to destroy the snags. We have had to be content with merely displacing them, removing them from places where they are obstructions and redepositing them in positions where they are least likely to become again dangerous. With more liberal appropriations it would be desirable to improve our system by taking out all the snags and destroying them. If the river were once thoroughly treated in this way, a comparatively small sum, perhaps no more than is now expended yearly, would maintain the channels free from snags. In order to carry out this plan, it would be necessary for the United States to build a snagboat, equipped with heavy hoisting machinery. Such a boat could be built for the sum of \$30,000.

There is no boat on the river suitably equipped for this work, and at present there is no inducement for private parties to provide a boat of this kind.

Other difficulties of navigation in the upper river are found in the shoal places, which are generally caused by too wide a bed or by a division of the channel into two parts. The closure of one of these channels, or the contraction of the bed when too wide, as a rule, remedies the difficulty, which, however, in the shiftings of the river, may be liable to reappear in another place at some time in the future. One such place is found at Lincoln Bend, near the Chico Landing.

In the ever-changing shiftings of the river bed between these dikes of hard pan, it happens sometimes that its course between two given points is many times the rectilinear distance. These convolutions in time correct themselves by the river taking a short cut over a neck of ground which shortens its length one or more miles.

It is occasionally and under special circumstances good policy to hasten this natural movement, although the system of cutting off cannot be recommended as a policy. It happens sometimes, as it is at Princeton, 20 miles above Colusa, that the river in its windings threatens to leave a good landing and in this way to work great injury to the landing and to the surrounding country tributary to the village.

The upper limit of our treatment of the river has thus far been Colby's Landing, which is 210 miles above the mouth. The river was in former years navigated to Red Bluffs, which is some 50 miles farther by the river. Since the railroad has reached this point steamboats have abandoned the upper 50 miles of the river. The natural difficulties due to rapids and snags are here very great. No recommendation has heretofore been made for the improvement of this upper section, but the day may come when the interests of this upper district will justify some improvement of the channel.