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PAPERS

RELATING TO

THE SIDHNAI CANAL PROJECT IN THE PUNJAB.

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PREFACE.

THE note by Colonel R. Home, R.E., which is printed on page 1 of this Selection, was written in 1883 to accompany the project of the Sidnai Canal, which was submitted to the Government of India for sanction in October of that year. The project, as then submitted, is described in Mr. Maclean's report which commences on page 6 of the Selection. Colonel Home, in submitting the project, mentioned (in para. 10 of the note above alluded to) that he considered it would be necessary to make certain additions to the weir across the Ravi which, in Mr. Maclean's estimates, was put down at Rs. 31,684 only, and was designed to be simply a wall across the river with its crest at bed level. Colonel Home added Rs. 75,000 to the estimates in order to provide for standards and shutters or other means of holding up the water. The general abstract of the estimate, which is given on page 22 of the Selection, includes the above addition (which eventually took the form of a needle weir), and works up to the sum (Rs. 7,74,480), which is mentioned in para. 13 of Colonel Home's note as being the estimated cost of the project. The forecast statements which are printed on pages 3 to 6 are based on the same capital cost, that is :—

	Rs.
Direct charges	7,48,727
Indirect charges	25,753
TOTAL .	7,74,480

2. The "Description of the head works of the Sidnai Canal," commencing at page 30, was written in 1888 by Mr. Maclean. In paras. 1 and 2 of Chapter II (page 31) will be found a detail of the subsidiary estimates which were sanctioned in order to provide for the necessary additions to the weir. A description is given in the same chapter of the construction of the weir, and of the working of the needles and shutters down to the time when the report was written.

3. The needle lock which has been constructed in the weir was not originally contemplated, as it was not then known that the Ravi was used for navigation at any season of the year. The lock allows of the maintenance of a certain amount of boat traffic which had always existed during the months that the river is in flood.

4. Up to the end of the year 1887-88, the capital expenditure on the Sidnai Canal has been Rs. 7,10,124 for direct charges as compared with the estimate of Rs. 7,48,727. The area irrigated in 1887-88 was 75,284 acres as compared with 21,000 acres provided in the forecasts (page 5 of Selection) and the net revenue derived from the works in that year was Rs. 1,01,752 as compared with Rs. 29,750, which was estimated. The canal paid 13·84 per cent. on the total capital, direct and indirect, invested in it at the end of the year 1887-88.

By order,

R. B. BUCKLEY,

Under Secy. to the Govt. of India, P. W. Dept.

20th May 1889.

LIST OF PLANS.

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PAPERS

RELATING TO

THE SIDHNAI CANAL PROJECT IN THE PUNJAB.

Note by COLONEL R. HOME, R.E., Chief Engineer, Irrigation Works, Punjab, on the Sidhnai Canal Project.

Alternative estimates for a permanent and for an inundation canal from this reach of the River Ravi were submitted by Mr. E. C. Palmer in 1875. Soon after their receipt they were reviewed by Colonel Brownlow, who then officiated as Chief Engineer in this Branch; he was of opinion that the data on which the weir and river works of the larger project were designed could not be considered trustworthy, and inclined to the smaller inundation project if the Financial Commissioner's estimate of the probable returns should give a sufficient percentage on the estimated outlay. There was considerable delay in obtaining the Financial Commissioner's opinion, and in the meantime, on account of the increased expenditure on the other large schemes then in progress, and of doubts whether the alignment of the proposed canal was the most favourable that could be obtained, the project remained in abeyance.

2. In these projects the head of the canal was located at the top of the straight reach (which is called the Sidhnai) of the Ravi; the course of the river immediately above it is singularly tortuous, and as the banks are comparatively low, in high floods the water spills over the left bank; in 1875 there was also serious erosion of that bank, and fears were entertained that the river might take to an old channel (the Sukráwa), which flowed direct to Mooltan. Of late years the river has cut through one of the narrow necks, and its course being thus straightened, all erosion of the left bank has ceased. Surveys made during the present year also show that this improvement has reduced the tendency to spill over the bank.

3. Mr. Palmer's alignment, owing to the position which he had chosen for the head of the canal, for many miles followed a depression with the object of saving excavation, and the delivery of water on to the surrounding country thus became more difficult and expensive.

4. On reconsidering the matter with reference to the present project it appeared that there was ample scope for a canal starting from any point in the reach, and moreover that on account of the numerous "jhallárs" on the right bank of the river it was desirable that the canal head should be placed as far down the reach as possible. An inspection of the contour map showed that the abandoned channel of the Ravi, below Sarai Sidhu, occupied the water-shed of the country, and that to obtain the greatest effect with the least expenditure the canal should be located on this water-shed. Having arrived at these conclusions, the selection of a site for the canal head evidently depended on the determination of a point on the river from which water could be delivered by a channel with suitable slope on to the ridge occupied by the old Ravi; the selection also depended to some extent on stability of the section of the river channel. Both requirements are met at the site now selected at Theyráj, where the section is sufficiently narrow (770 feet across) to render any works that may hereafter be required to raise the level of the water comparatively inexpensive, whilst at the same time the width is great enough to prevent any excessive rise of water in floods and to allow of the water passing away from such works with a manageable velocity. The bed and banks of the river at and near this point are of stiff brown clay.

5. The section given on the line of the proposed canal in sheet No. 3 of the plans forwarded with the project shows that the junction of the head with the ridge is attained under very favourable circumstances, and that the old channel of the river can be utilised for a great portion of its course. The section of the old Ravi is very clear and defined; in most places the bed is not more than 5·0′ below the level of the country, and as the soil is firm, the channel has a rectangular section; the bed, however, is much wider than is required for the canal, and, as it is now covered with trees and scrub jungle, it is proposed to clear from one bank a width sufficient for the canal, and to allow the rest of the old channel to silt up, which there is no doubt it will do in a few years after water has been admitted into the canal.

6. The cuts-off which are required to increase the slope of the channel are designed of the correct section for the future canal, and as they are of less width than the old channel, the process of silting before alluded to will be thereby encouraged. These cuts-off have been carefully planned so as to keep up a nearly constant velocity on all the reaches of the canal; this will be seen in Appendices 1 and 2 attached to the estimate, and the slope of the country away from the canal is so strong that nearly the same velocity can be maintained in the distributaries.

7. It is apparent from the daily records, which have been maintained of the height of the river at Baghdád since 1875, that the high flood level as stated by Mr. Palmer is correct, and that a maximum discharge of 18,000 cubic feet per second at this point of the river is not likely to be exceeded. The Ravi has no large tributaries after it passes Lahore, and its course lies through a tract of sandy country. There can be now no doubt that, like all other Punjab streams which have only a small perennial flow, the flood-waters of the Ravi spreading over a wide bed of sand which is at other times dry are absorbed by it to such an extent that only a small proportion reaches Baghdád, which is situated a few miles above the junction of the Ravi with the Chenab.

8. These gauge records also show that all idea of constructing a perennial canal from this part of the river must be abandoned, and that only a limited supply can be counted on for an inundation canal. Twice since 1875 has the Ravi been absolutely without flow during the cold weather for a month at a time; calculations of returns have therefore in the present project been based on the data derived from existing inundation canals where the rabi crop in default of seasonable winter rains is perfected by well irrigation. The circumstances of the canal, despite the variable nature of the supply, are, however, so favourable that its success as an irrigation project may be safely predicted.

9. The only masonry works on the canal, besides the head works, are bridges and heads for the distributary channels. They are all of the usual type, and call for no remark.

10. The head works are described in paragraphs 52 to 55 of the Executive Engineer's report. The regulator is a massive structure of the ordinary design. In the main trough of the river there is a small deep channel which winds about from side to side and which carries the ordinary cold weather supply of the river. It would manifestly have been a waste of command to take this small channel into account in fixing the level of the bed of the canal; the depressions have therefore been filled in with substantial weirs, which are connected by a wall across the bed of the river. The crests of the weirs, the top of the connecting wall and the floor of the regulator are all at the same level, *viz.* that of the general bed of the river. The arrangements appear to be sufficiently strong and complete; but I think that it will be advisable to provide for some additions to the head works, which will, in my opinion, be found necessary hereafter to maintain the supply in the canal at the beginning and end of the irrigating season, at which times, as will be seen from Appendix No. 4, the quantity of water in the river varies considerably in different years. These additions will probably take the form of standards and gates or planks, such as have been successfully employed in similar cases on the canals of the North-Western Provinces. Their use will also entail additional protection to the bed of the river. I have therefore increased the total of the Executive Engineer's estimate by a lump sum of R75,000, which will, I think, be sufficient for the purpose.

11. The sections of the canal channel have been designed with reference to the size and position of the distributaries (see Appendix II). The distribution of the supply is not likely to undergo much alteration, but the lines for the distributary channels are only indicated. Their length and direction may, however, be accepted as approximately correct. No levels have been taken in connection with No. 4 Distributary. There is a large area of waste land to the south of the Railway, and the numerous channels of which traces are still to be seen show that this tract was well cultivated before the Ravi changed its course; the direction of the old water-courses is nearly due north and south.

12. The Executive Engineer notes in paragraph 81 of his report that, after the completion of the masonry works and of as much of the earth-work as will allow of water being admitted into the canal, there will be no necessity for maintaining a separate divisional establishment, and the work will be completed by the existing Lower Sutlej and Chenab Canals Division, to which this canal will then be attached as a sub-divisional charge.

13. The financial results of the project are stated in Executive Engineer's paragraph 80 to be 8·16 per cent. on an outlay of R6,73,488. These figures will be modified by a correction in the item of leave and pension allowances which is necessitated by Government of India Circular No. XIII, dated 22nd August 1883, and also by the addition of R75,000, alluded to in

paragraph 10 of this note, and its percentages to the cost of the river works. These alterations will raise the Capital Account to R7,74,480, on which a net income of R55,000 will give a percentage of 7·10, which may still be considered a sufficiently favourable return.

14. The Executive Engineer's figures for income contemplate the employment of statute labor for the maintenance of the canal, and his water-rates are consequently fixed (see paragraphs 18 and 20 of his report) in accordance with those in force on other inundation canals in the Mooltan District. He has erred on the side of safety in assuming the low duty of 60 acres per cubic foot of discharge.

15. The Financial Commissioner, in answer to an enquiry as to the rates that could be levied if this canal were maintained under the same system as all other canals in the Province except the existing Mooltan and Muzaffargarh Canals on which statute labor is employed, states in his No. 74 C., dated 29th June 1883 (copy of which is appended to the estimates), that average rates of R2·5 for the kharif and R1·5 for the rabi could be assessed.

16. Taking the proportion of kharif to rabi area as 2 to 1, as in the Montgomery Canals of the Upper-Sutlej series, which are similarly situated as regards freedom from river spills, the gross revenue of the Sidhnai Canal would be—

	Acres.		R
Kharif	32,000	@ R2-8 per acre	80,000
Rabi	16,000	@ R1-8 „	24,000
TOTAL	48,000		1,04,000

The total charge for maintenance including establishment, on the Upper Sutlej series is less than 9 annas and on the Lower Sutlej and Chenab Canals less than 12 annas per acre irrigated. In both cases the rate covers the cost of constructing new heads to the canals—an item which in every year forms a very considerable part of the maintenance charges, but which will not appear in those of the Sidhnai Canal. It may therefore be assumed that 12 annas per acre is a safe allowance for the maintenance of this canal.

17. Under these conditions the Revenue Account will be as follows :—

	R
Gross revenue as above	1,04,000
Deduct maintenance—	
48,000 acres @ 12 annas per acre	36,000
Balance net revenue	68,000

which is equivalent to a percentage of 8·78 on a capital of R7,74,480.

18. There is no wish to introduce a system of statute labor on this canal; but the above calculations show that, whichever system may be pursued, the return from the outlay on its construction will be highly remunerative.

The project has been prepared by Mr. L. F. Maclean, Executive Engineer, under my instructions, and it has been drawn up in a very creditable manner.

SIDHNAI CANAL PROJECT.

No. 1.

Summary of the Estimated Direct Charges to Capital Account.

YEAR.	Works.	Establishment	Tools and Plant.	TOTAL.
1	2	3	4	5
	R	R	R	R
First, 1883-84 and Preliminary in 1882-83	62,720	26,990	4,000	93,710
Second, 1884-85	1,75,000	43,750	5,240	2,23,990
Third, 1885-86	1,20,000	27,850	2,560	1,50,410
Fourth, 1886-87	70,000	14,000	1,600	85,600
Fifth, 1887-88	65,000	13,000	1,450	79,450
Sixth, 1888-89	31,000	7,000	900	38,900
Seventh, 1889-90	31,000	7,000	900	38,900
Eighth, 1890-91	30,217	6,650	900	37,767
TOTAL	5,84,937	1,46,240	17,550	7,48,727

R. HOME, *Colonel, R.E.*,
Chief Engineer, Irrigation Works, Punjab.

No. 2.

Summary of the Estimated Indirect Charges to Capital (excluding Interest).

Year.	Capitalisation of land revenue abated.	Loss by exchange on payments in England.	Charges for leave and pension allowances.	Total.
1	2	3	4	5
	R	R	R	R
First, 1883-84	5,280		3,778	9,058
Second, 1884-85	...		6,125	6,125
Third, 1885-86	...		3,899	3,899
Fourth, 1886-87	...	*Nil*	1,960	1,960
Fifth, 1887-88	...		1,820	1,820
Sixth, 1888-89	...		980	980
Seventh, 1889-90	...		980	980
Eighth, 1890-91	...		931	931
Total	5,280	*Nil*	20,473	25,753

R. HOME, *Colonel, R.E.,*
Chief Engineer, Irrigation Works, Punjab.

No. 3.

Estimate of growth of Irrigation and Revenue Receipts and Charges.

Year.	Irrigated area at end of year.	Revenue Receipts and Charges. Gross Revenue due to works. Direct receipts.	Gross Revenue due to works. Enhanced land revenue, or indirect revenue.	Gross Revenue due to works. Total.	Charges, both direct and indirect, against Revenue Account.	Net Revenue due to works. Including enhanced land revenue.	Net Revenue due to works. Excluding enhanced land revenue.
1	2	3	4	5	6	7	8
	R	R	R	R	R	R	R
First, 1883-84	...	...		...	...	...	...
Second, 1884-85	2,000	2,666·6		2,666·6	500	2,166·6	2,166·6
Third, 1885-86	6,000	8,000·0		8,000·0	1,000	7,000·0	7,000·0
Fourth, 1886-87	13,000	17,333·3		17,333·3	2,000	15,333·3	15,333·3
Fifth, 1887-88	21,000	28,000		28,000	4,000	24,000	24,000
Sixth, 1888-89	30,000	40,000		40,000	6,000	34,000	34,000
Seventh, 1889-90	39,000	52,000		52,000	7,500	44,500	44,500
Eighth, 1890-91	48,000	64,000		64,000	9,000	55,000	55,000
Ninth, 1891-92	48,000	64,000	*Nil.*	64,000	9,000	55,000	55,000
Tenth, 1892-93	48,000	64,000		64,000	9,000	55,000	55,000
Eleventh, 1893-94	48,000	64,000		64,000	9,000	55,000	55,000
Twelfth, 1894-95	48,000	64,000		64,000	9,000	55,000	55,000
Thirteenth, 1895-96	48,000	64,000		64,000	9,000	55,000	55,000
Fourteenth, 1896-97	48,000	64,000		64,000	9,000	55,000	55,000
Fifteenth, 1897-98	48,000	64,000		64,000	9,000	55,000	55,000
Sixteenth, 1898-99	48,000	64,000		64,000	9,000	55,000	55,000
Seventeenth, 1899-1900	48,000	64,000		64,000	9,000	55,000	55,000
Eighteenth, 1900-1901	48,000	64,000		64,000	9,000	55,000	55,000

T. G. WALKER,
Senior Secretary to Finl. Commr., Punjab.

R. HOME, *Colonel, R.E.,*
Chief Engineer, Irrigation Works, Punjab.

No. 3 A.

Alternative Estimate of growth of Irrigation and Revenue Receipts and Charges with reference to paragraphs 16 and 17 of Chief Engineer's Note.

Year.	Irrigated area at end of year.	Revenue Receipts and Charges. Gross Revenue due to works. Direct receipts.	Gross Revenue due to works. Enhanced land revenue, or indirect revenue.	Gross Revenue due to works. Total.	Charges, both direct and indirect, against Revenue Account.	Net Revenue due to works. Including enhanced land revenue.	Net Revenue due to works. Excluding enhanced land revenue.
1	2	3	4	5	6	7	8
	R	R	R	R	R	R	R
First, 1883-84	...	...	...	...	...	...	...
Second, 1884-85	2,000	4,333	...	4,333	1,500	2,833	2,833
Third, 1885-86	6,000	13,000	...	13,000	4,500	8,500	8,500
Fourth, 1886-87	13,000	28,167	...	28,167	9,750	18,417	18,417
Fifth, 1887-88	21,000	45,500	...	45,500	15,750	29,750	29,750
Sixth, 1888-89	30,000	65,000	...	65,000	22,500	42,500	42,500
Seventh, 1889-90	39,000	84,500	...	84,500	29,250	55,250	55,250
Eighth, 1890-91	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Ninth, 1891-92	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Tenth, 1892-93	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Eleventh, 1893-94	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Twelfth, 1894-95	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Tirteenth, 1895-96	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Fourteenth, 1896-97	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Fifteenth, 1897-98	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Sixteenth, 1898-99	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Seventeenth, 1899-1900	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000
Eighteenth, 1900-1901	48,000	1,04,000	...	1,04,000	36,000	68,000	68,000

R. HOME, *Colonel, R.E.,*
Chief Engineer, Irrigation Works, Punjab.

No. 4.

Estimate of Net Financial Results of ten years after the probable date of completion of the work.

Year.	Direct Capital outlay during the year.	Direct Capital outlay to end of year.	Simple interest at 4 per cent on Capital outlay to end of previous year plus half outlay during year.	Net revenue, including enhanced land revenue, column 7 of Table 3.	Simple interest less net revenue.	Net revenue less simple interest.
1	2	3	4	5	6	7
	R	R	R	R	R	R
First, 1883-84	94,000	94,000	1,880	...	1,880·0	...
Second, 1884-85	24,000	3,18,000	8,240	2,166·6	6,073·3	...
Third, 1885-86	1,50,000	4,68,000	15,720	7,000·0	8,720·0	...
Fourth, 1886-87	86,000	5,54,000	20,440	15,333·3	5,106·7	...
Fifth, 1887-88	79,000	6,33,000	23,740	24,000	...	260
Sixth, 1888-89	39,000	6,72,000	26,100	34,000	...	7,900
Seventh, 1889-90	39,000	7,11,000	27,660	44,500	...	16,840
Eighth, 1890-91	37,727	7,48,727	29,194	55,000	...	25,816
Ninth, 1891-92	...	7,48,727	29,949	55,000	...	25,151
Tenth, 1892-93	...	7,48,727	29,949	55,000	...	25,151
Eleventh, 1893-94	...	7,48,727	29,949	55,000	...	25,151
Twelfth, 1894-95	...	7,48,727	29,949	55,000	...	25,151
Thirteenth, 1895-96	...	7,48,727	29,949	55,000	...	25,151
Fourteenth 1896-97	...	7,48,727	29,949	55,000	...	25,151
Fifteenth, 1897-98	...	7,48,727	29,949	55,000	...	25,151
Sixteenth, 1898-99	...	7,48,727	29,949	55,000	...	25,151
Seventeenth, 1899-1900	...	7,48,727	29,949	55,000	...	25,151
Eighteenth, 1900-1901	...	7,48,727	29,949	55,000	...	25,151
				Net Result	+ 2,80,546	

T. G. WALKER,
Senior Secretary to Finl. Commr., Punjab.

R. HOME, *Colonel, R.E.,*
Chief Engineer, Irrigation Works, Punjab.

No. 4 A.

Alternative Estimate of Net Financial Results of ten years after the probable date of completion of the work with reference to paragraphs 16 and 17 of Chief Engineer's Note.

1 Year.	2 Direct Capital outlay during the year.	3 Direct Capital outlay to end of year.	4 Simple interest at 4 per cent. on Capital outlay to end of previous year plus half outlay during year.	5 Net revenue, including enhanced land revenue, column 7 of Table 3.	6 Simple interest less net revenue.	7 Net revenue less simple interest.
	R	R	R	R	R	R
First, 1883-84	94,000	94,000	1,880	...	1,880	...
Second, 1884-85	2,24,000	3,18,000	8,240	2,833	5,407	...
Third, 1885-86	1,50,000	4,68,000	15,720	8,500	7,220	...
Fourth, 1886-87	86,000	5,54,000	20,440	18,417	2,023	...
Fifth, 1887-88	79,000	6,33,000	23,740	29,750	...	6,010
Sixth, 1888-89	39,000	6,72,000	26,100	42,500	...	16,400
Seventh, 1889-90	39,000	7,11,000	27,660	55,250	...	27,590
Eighth, 1890-91	37,727	7,48,727	29,194	68,000	...	38,806
Ninth, 1891-92	...	7,48,727	29,949	68,000	...	38,051
Tenth, 1892-93	...	7,48,747	29,949	68,000	...	38,051
Eleventh, 1893-94	...	7,48,727	29,949	68,000	...	38,051
Twelfth, 1894-95	...	7,48,727	29,949	68,000	...	38,051
Thirteenth, 1895-96	...	7,48,727	29,949	68,000	...	38,051
Fourteenth, 1896-97	...	7,48,727	29,949	68,000	...	38,051
Fifteenth, 1897-98	...	7,48,727	29,949	68,000	...	38,051
Sixteenth, 1898-99	...	7,48,727	29,949	68,000	...	38,051
Seventeenth, 1899-1900	...	7,48,727	29,949	68,000	...	38,051
Eighteenth, 1900-1901	...	7,48,727	29,949	68,000	...	38,051
				Net Result		+ 4,52,786

R. HOME, *Colonel, R.E.*,
Chief Engineer, Irrigation Works, Punjab.

Report on the Sidhnai Canal Project, 1883.

General description of country affected.

The country for which irrigation is provided by this project is situated in the Sarai Sidhu and Mooltan Tahsils of the Mooltan District, and is bounded on the north by the River Ravi, on the west by the Khúdil Canal and the Sarai Sidhu and Mooltan road on the south by the Sindh, Punjab and Delhi Railway, and on the east by a line which, beginning at Theyráj, passes through Makhdúmpur, and from thence to Rashida, a station on the Sindh, Punjab and Delhi Railway. In addition to this, provision has been made in the project for the irrigation of 9,500 acres south of Rashída.

Area commanded.

2. The area commanded is about three hundred square miles, or 192,000 acres. Of this the present project provides for the irrigation of 48,000 acres, or 25 per cent. of the whole.

Required discharge of canal.

3. Assuming the duty obtainable from 1 cubic foot of water per second to be 60 acres, a discharge of 800 cubic feet per second is required to irrigate this area.

Quality of the soil.

4. The quality of the soil is generally good, and where water is available, luxuriant crops are grown. It is rare to see reh on the surface.

Rainfall in the Sarai Sidhu Tahsil.

5. Below is a statement showing the rainfall in the Sarai Sidhu Tahsil for every month of the year during the ten years ending 1881-82, from which it appears that the average yearly rainfall for that period was 5·92 inches.

Name of Month.	1872-73.	1873-74.	1874-75.	1875-76.	1876-77.	1877-78.	1878-79.	1879-80.	1880-81.	1881-82.
April	0·40	...	...	...	...	0·60	0·60	...	...	...
May	0·10	3·0	...	...	...	0·90	...	...	...	...
June	0·90	...	...	...	1·40	1·00	1·00	2·60	0·40	0·70
July	1·40	1·65	1·90	0·60	2·50	1·60	1·40	1·10	0·30	0·80
August	1·90	2·30	0·30	1·70	0·30	...	4·10	1·40	...	1·70
September	1·30	...	0·50	...	...	6·70	0·50	...	...	...
Total	6·00	6·95	2·70	2·30	4·20	10·80	7·60	5·10	0·70	3·20
October	...	...	...	...	...	...	...	...	...	...
November	...	...	...	...	0·10	0 20	...	...	...	...
December	...	0·85	...	...	...	0·70	...	...	0·30	...
January	0·40	0·20	...	...	0·50	...	...	...	...	0·30
February	...	...	...	...	0·30	0·10	...	0·40	1·20	0·60
March	...	0·10	...	0·10	1 00	0·10	1·00	...	1·20	...
Total	0·40	1·15	...	0·10	1 90	1·10	1·00	0·40	2·70	0·90
Total for year	6·40	8·10	2·70	2·40	6·10	11·90	8·60	5·50	3·40	4·10

Famine.

6. The population of the country affected is so small, being about 25000, or a little over 80 per square mile, that a famine is almost impossible.

Nature of country.

7. Most of the country is covered with jungle, which, to within about three miles of the Ravi, consists of sirkánda grass, and further away from the river, of jhál, karíl, tamarisk and jhand, in varying proportion.

Existing irrigation from jhalárs on the banks of the river.

8. Along the banks of the Ravi there is extensive irrigation from jhalárs, but beyond the direct reach of the river wells are very scattered.

Depth of water in wells.

9. The observations shown in Appendix No. 14 were made on the depth of water below the surface of the ground in the wells during the cold season 1882-83. Along the bank of the river and within a mile from it, the depth varies from 20 to 25 feet; at 5 miles from the river the depth is about 35 feet; at 12 miles 40 feet; and from thence to Rashída, the depth gradually increases to 50 feet.

Quality of water in wells.

10. The water in the wells is good, and little or no reh results from irrigating with it.

Existing well irrigation.

11. The only irrigation now practised in the tract affected by the canal is from wells, but the lift is too great throughout the tract to admit of economical irrigation from this source.

The exact area irrigated is not known, but it is probably 4,800 acres, or $\frac{1}{40}$th of the area commanded by this canal.

Agricultural seasons.

12. The character of the agricultural seasons is well defined in the Mooltan District, and the following crops are usually grown where water is available:—

Kharíf—Sugarcane, indigo, rice, cotton, jowár, bájra, mung, china, til, samach.

Rabi—Wheat, barley, turnips, gram.

Crops most suitable for canal.

13. In the years 1879 and 1880, the average supply of water in the river during the month of June was less than 800 cubic feet, and even had it been possible to divert the whole available volume of water in the river into the canal, such crops as sugarcane, indigo, rice and cotton would probably have suffered from want of water.

14. It would be safer to look forward to the cultivation of such crops as bájra, til, china, mung, samach, which do not require much water until the month of July.

Dates of sowing and reaping different crops.

15. Below is a statement showing the time of the year at which the different crops in the Mooltan District are sown and reaped:—

Name of Crop.	Date of Sowing.		Date of Reaping.		Remarks.
	From	To	From	To	
Sugarcane	15th February	31st March	15th October	15th January.	For the former year's indigo water is wanted, if possible, by 15th April; if not watered till 15th May it will suffer.
Indigo	15th April	31st May	15th August	15th October	
Rice	1st June	15th July	15th September	1st October	Water is required up to 15th September.
Cotton	15th May	15th June	15th October	31st December	Ditto ditto
Jowár (Millet)	Ditto	Ditto	15th July	15th September	This crop can be sown at any time almost, and requires water for two months.
Bájra (Millet)	15th July	15th August	15th October	15th November	Two or three waterings suffice for this crop.
Mung	Ditto	15th September	15th September	15th October.	
China	15th August	Ditto	15th October.		
Til	15th July	Ditto	15th November	15th December	Sown largely on *sailába* lands; one or two good floodings sufficient.
Samach	15th June	15th July	15th September	15th October.	
Rabi.					
Wheat	15th October	15th December	15th April	15th May.	
Barley	15th September	15th November	15th March	15th April.	
Turnips	15th August	15th October	December	March.	
Gram	Ditto	Ditto	15th March	15th April.	

Markets.

16. The principal market for the agricultural produce of the district is Mooltan, and all the area commanded by this canal is within easy reach of this place either by road or rail.

The Ravi is the only line of water carriage.

Trade routes.

17. The existing trade routes of the district are the roads from Mooltan to Lahore, Sarai Sidhu and Jhang, and the Sindh, Punjab and Delhi Railway.

Water-rates proposed.

18. The proposals for levying water-rates for this canal have been various.

The rates on the Upper Sutlej Inundation Canals are about ₹1·8 per acre for kharíf crops and ₹0·9 for rabi, and Mr. Palmer, in his project of 1875 for this canal, proposes ₹2 for kharíf and ₹1 for rabi, plus a water-advantage rate of 12 annas per acre, the cost of maintenance being defrayed by the canal. These rates are fair in the opinion of Executive Engineer, as, with the exception of a very small amount near the heads of the distributaries, the irrigation will all be by flow.

Irrigation to be "flow."

19. For the purpose of this project the whole irrigation may be assumed to be "flow" without any error of consequence.

Water-rates fixed by Deputy Commissioner.

20. The Deputy Commissioner has been asked for his opinion as to what rates should be charged for water on this canal, and has given it in detail in his No. 987 of 29th June 1883, to the address of Superintendent of Works. There are two classes of land commanded by this canal, one being Government waste, and the other included in village boundaries. The Deputy Commissioner is of opinion that the former should pay ₹1-8 per acre and the latter 8 annas for the whole year.

21. The land revenue of the district is about to be fixed under a new settlement for 20 years, which is now under the consideration of Government, the general terms of which are not known; but the Deputy Commissioner states, in the above-mentioned letter, that the canal will not be entitled to any share of the increase of land revenue until the ensuing settlement.

Of course any income from this source will put the financial aspects of the project in a more favourable light.

Chher system.

22. The Deputy Commissioner has also recommended the introduction of the "chher" system on this canal.

Drainage and Protective Works.

23. There are no drainage or protective works required, except the small drainage diversion cut, commencing at the 7th mile from the head of the canal, and shown on contour map No. 1.

Attitude of landholders towards the canal.

24. The landholders of the district are anxious for the canal, and if a proper rate is fixed, they will gladly avail themselves of the water. One of the most influential of the landowners (Hamid Shah) promised Mr. Garbett to take up 20,000 acres, and to bring it all under cultivation in seven years. The Deputy Commissioner has also given his opinion that the land is likely to be taken up freely, and that not less than from 6,000 to 8,000 acres per year would be brought under cultivation.

Extension of irrigation.

25. The probable yearly extension of irrigation, until the whole proposed area is brought under cultivation, is shown in the following table:—

Year.	Area brought under cultivation.	Total under cultivation.	Remarks.
1884	.....	.....	Canal under construction.
1885	2,000	2,000	Ditto.
1886	4,000	6,000	Canal being extended.
1887	7,000	13,000	Ditto.
1888	8,000	21,000	Ditto.
1889	9,000	30,000	Ditto.
1890	9,000	39,000	Ditto.
1891	9,000	48,000	Ditto.

Time required for completion of canal.

26. According to this the whole area would be brought under cultivation in 1891, or eight years from the commencement of the canal.

Commencement of surveys.

27. Under orders from the Superintending Engineer, Deraját Circle, in his No. 1912, dated 22nd December 1882, Executive Engineer took charge of the Sidhnai Canal Division on 23rd December 1882, and commenced the necessary surveys in January 1883.

Selection of head.

28. The instructions given by Superintending Engineer were to select a point in the Sidhnai reach of the Ravi, as near the lower end as possible, from which the canal could in the most economical way be made to join the main ridge of the country which is coincident with the course of the old Ravi, and to run trial lines and take levels so as to construct a contoured map in greater detail than that prepared by Mr. Palmer in 1875.

Nature of canal proposed.

29. The alignment was to be arranged expressly to suit a simple inundation canal without either weir or masonry works, and so as to utilise the bed of the old Ravi as a main channel wherever possible.

Cross-sections of Ravi.

30. In order to select a head cross-sections of the river were taken at every mile of the Sidhnai reach—see plans Nos. 17, 18, 19—and the site of the canal head was fixed at cross-section No. 9, opposite Theyráj.

Reasons for selecting head opposite Theyráj.

31. The principal reasons in favour of this site are—

(1)—The section of the river is a good and compact one.

(2)—The bed of the river is higher here than for some distance up-stream—(see longitudinal section along deep channel of Ravi on sheet No. 12.)

(3—The country slopes rapidly away from the river, as can be seen from contour map No. 1.

(4)—Any line starting from higher up the river would be more expensive on account of deeper cutting.

(5)—Whilst below this point the river channel is wider, and shows signs of being unstable.

(6)—The canal runs in a strip of Government waste land, the land on each side being included in village boundaries and valued at not less than ₹50 per acre.

32. Three trial lines of levels were taken, Nos. 1, 2, 3 (see contoured map and sheet No. 12), as much as a basis for levelling operations as anything else; but No. 2, joining the main ridge of the country at 60,000 feet from the river, was regarded as a possible line for the canal.

Trial lines.

For an ordinary inundation canal the bed would have to take out of the Ravi at Theyráj at a reduced level of about 450·00, which is that of the lowest point of the river bed.

33. The levels taken along Trial Line No. II, following the ridge of the country, shows that at 140,000 feet from the head the reduced level of the natural surface of the ground is 430·00, so that if the canal bed took out at reduced level 450·00, with a slope of 1 in 7,000, it would coincide with the natural surface level at reduced distance, 140,000 feet, or 28 miles from the river.

Trial Line No. II.

34. As this is an easy gradient for flowing water, Executive Engineer was led to think, and the Superintending Engineer concurred in the opinion, that up to this point, which is where the canal now designed crosses the Mooltan and Lahore road, the old Ravi could not to any great extent be economically used as a channel for the canal, as the cutting would be heavy and with the same gradients a straight line would run out of this heavy cutting at a shorter distance from the head than a more tortuous one.

35. The area enclosed with red lines on the contoured map, and on which are drawn contours for every foot of rice, was surveyed and levelled during the cold season of 1882-83, with the object of obtaining accurate data on which to determine the best alignment for the canal, and although provision has been made in the project for irrigating 9,500 acres south of the Sindh, Punjab and Delhi Railway, the surveys have been confined to the tract of country between the Ravi and the Railway.

Area surveyed this season.

36. In the beginning of April, when the surveys and levels had been completed and plotted, the results were laid before the Chief Engineer, and the present project has been prepared in accordance with the orders contained in the note forwarded with his No. 2401 I, dated 17th April 1883, to Superintendent of Works, Deraját Circle.

Results of surveys laid before Chief Engineer.

37. In consequence of the adoption of a weir across the deep channel, and the canal bed being thereby raised 4·5 feet, to reduced level 454·50, the cutting has been much diminished, and it has been found possible to join the old Ravi at 56,000 feet from the river, and to utilise it considerably as a channel for the canal.

Weir and regulator adopted.

Old Ravi used for a channel.

Longitudinal and cross-sections of canal.

38. The longitudinal section of main canal is given on plan No. 3, and cross-sections at several typical points on plan No. 9.

In the direct line to join the old Ravi there will be banks 10′ and 15′ wide, but, after joining the old Ravi, the banks will be 6′ wide at top, and will be made on the banks of the old Ravi, the canal-water being allowed to flow all over the old channel.

39. For the most part the old bed of the Ravi is covered with shrub and brushwood jungle, and it is intended to cut through this a channel for the canal, varying from 20′ to 10′ greater than the calculated width of the canal bed.

Jungle in old Ravi to be partially cut.

40. The remaining jungle will arrest the flow of water at the sides, and tend to deposit silt, so as to form a defined channel for the canal of a proper width.

Effect of jungle left.

41. It is intended only to excavate the canal to half width in the first instance, but all the masonry works will be built as soon as possible, and of full capacity.

Excavation of half canal in first instance.

Development of canal.

42. The canal and its distributaries will afterwards be completed as the growth of irrigation necessitates.

43. The final alignment of the canal is shown on contoured map No. 1. Leaving the Ravi at right angles, it runs straight for 2,000′, where a curve to the right of 5,000′ radius commences, ending at R. D. 18,000. From this point the canal runs nearly due west to R. D. 26,000, in order to avoid a drainage depression, in which a more direct line would not have sufficient cutting to make up

Final alignment of main canal.

the banks. From 26,000′ to 30,000′ there is a curve to the left of 7,500′ radius, and from this point it runs straight to the old Ravi opposite the village at Chauparata at R. D. 52,000. From this to R. D. 165,000, near the Mooltan and Lahore road, the canal runs mainly in the old Ravi, such bends being cut off as are necessary to give a proper gradient to the canal bed. From this point to the Railway culvert near Rashída the canal runs very nearly south, but it is not thought advisable to run much in the bed of the old Ravi, which below R. D. 175,000 is highly cultivated and badly defined.

Junction with old Ravi.

Cutting of bends.

44. The area commanded by the canal is divided upon the contoured map into blocks which it is proposed to irrigate by the distributaries drawn on them.

Distributaries.

45. There are four main distributaries and six minor ones, and it is intended to have flow irrigation from all. Block No. 1, containing 30 square miles will be irrigated by minor distributaries 1 and 2, having an aggregate discharge of 86 cubic feet per second.

Flow irrigation.

Block No. 2, containing 55 square miles, will be irrigated by distributary No. 1, leaving the main canal at R. D. 56,000, and approximately following the line of an ancient watercourse (see cross-sections of distributary No. 1; sheet No. 13); the discharge of this distributary will be 158 cubic feet per second.

Block No. 3, containing 27 square miles, will be irrigated by minor distributaries, Nos. 3, 4, and 5, of an aggregate discharge of 78 cubic feet per second.

Block No. 4, containing 40 square miles, will be irrigated by distributary No. 2, with a discharge of 115 cubic feet per second.

Block No. 5, containing 8 square miles, will be irrigated by minor distributary No. 6; the area of this block is considerably more than 8 square miles, but a large portion of it is too high to admit of flow irrigation. This has been neglected in calculating the area.

Block No. 6 is 59 square miles, and it will be irrigated by distributary No. 3, which will have a discharge of 170 cubic feet per second.

Block No. 7, containing 27 square miles, will be irrigated by direct channels from the canal, the aggregate discharge of which will be 78 cubic feet per second.

46. Distributary No. 4 will irrigate a tract beyond the Railway with a discharge of 92 cubic feet per second, and will commence at the level of the Railway culvert at Rashída.

Passage under Railway at Rashída.

47. The final alignment of distributaries Nos. 1, 2 and 3 will be as far as possible along ridges formed by three ancient watercourses, the cross-sections of which are shown on sheets Nos. 13, 14, 15. It seems hardly possible to utilise the ancient watercourses themselves to any great extent on account of the high levels of their beds and spoil-banks.

Longitudinal sections, minor distributaries.

48. The longitudinal sections of the minor distributaries are drawn on plan No. 16.

49. The rates entered in the estimate for distributaries and minor distributaries have been arrived at as follows:—

		Per mile. R	a.	p.
Distributaries—	Earthwork	1,700	0	0
	Bridges	500	0	0
	TOTAL	2,200	0	0
Minor distributaries		1,500	0	0

The regulators for each distributary have been estimated for separately.

The Railway culvert at Rashída can be used as a regulator for branch No. 4.

50. It will be possible to run the distributaries almost entirely through Government waste land, so that the cost of land for them will be something very small.

Land for distributaries.

51. The velocities throughout the different reaches of the canal have been fixed as nearly as possible equal, as may be seen from Appendix No. 2. In the same Appendix will be found full information relative to the proposed discharge depths of water, bed widths, slopes of bed and velocities of different

Velocities.

reaches of the canal and of the distributaries. The formula adopted for calculating the discharges is that of Kutter ($Q = A \times 100\ C\sqrt{RS}$), as given in Jackson's Hydraulic Tables, the co-efficient of roughness used throughout being 0·025.

Description of Masonry Works.

52. The head works (see plans Nos. 4 and 5) will consist of a regulator with eight sluice openings of 10′ each, with 60° arches, springing from 5′ above canal bed, with jack piers 2·5′ thick:

Head works.

The main arches will be four in number, with spans of 22·5′, springing from piers 3′ thick at 6′ above canal bed. The curtain walls of the regulator and the river walls up and down stream are designed on wells 10′ below the lowest point of the present cross-sections of river.

53. Wells have been adopted in the design in preference to concrete, because they are more expensive, and sufficient information was not obtainable, when the water in the Ravi was low, to make it certain that the concrete foundations could be put in 10′ below river bed.

Well foundations

Should it be found afterwards that wells can be dispensed with, there will be a considerable saving in consequence.

54. The weir consists of a wall, 770′ long, founded on concrete in the centre, and on wells for 20′ from each bank.

Weir.

55. The wall in the deep channel on each side of the river will be protected by heavy pitching of Chiniot stone, with a slope of 1 to 3 on the up-stream and 1 to 12 on the down-stream side. The level of the crest of the weir will be the same as the floor of the regulator.

56. As the crest of the weir is nearly an equalising line for the present bed of the river, the discharges over it have been calculated as for a channel having a continuous slope of 1 in 12,000; this method is very nearly correct, as there is a considerable decrease in the depth of water, where the river widens out between Baghdád and Theyráj, and a consequent increase in the surface slope of the water.

57. Appendices Nos. 4, 5, 6 show the average discharge of the Ravi at Baghdád for every month of the year from 1875 to 1882, and for every half foot of depth of water on the gauge, and the discharge over the Proposed weir at Theyráj for every half foot of depth of water.

Discharges of Ravi at Baghdád and over weir.

From these tables the probable supply of water in the canal can be easily seen.

58. There are three bridges on the canal at reduced distances, 12,000, 44,000, and 165,000 at the crossing of the principal roads, and detailed designs are shown on sheets Nos. 6, 7 and 8.

Bridges.

59. Designs for heads of distributaries Nos. 1 and 3 have been drawn (see sheet No. 8), and the others will be similar in every respect with water-way suitable for each channel.

Distributaries' heads.

60. The buildings are all to be of a temporary nature; that shown on plan No. 10 is intended to be either at Sarai Sadhu or from other suitable place near the head of the canal, and is suited for the residence of the Engineer, who will be in charge of the works.

Buildings.

61. The bungalow shown on plan No. 11 is intended for rest-houses to be built at Ráepur, Kot Búta, Rashída and Ráwan (see map No. 1).

62. Flat mud roofs have been adopted, as they seem most suitable to the climate of this district.

Flat roofs.

63. Plantations will not be commenced until water has been admitted into the canal, and a uniform rate of ₹200 per mile has been adopted, as in the Chenab Canal Project.

Plantations.

64. Detail of the provision of the establishment is given in Appendix No. 8, and the total is 20 per cent. on the estimated outlay of works, the charge for Direction being 5 per cent.

Establishment.

Rates for Materials and Labour.

65. Fuel is expensive in this district on account of the demand for Mooltan and the Sindh, Punjab and Delhi Railway. It will probably cost not less than ₹30 for 400 cubic feet.

Fuel.

66. Stone in any quantity and of large size can be got at Chiniot and delivered at Sarai Sidhu for ₹20 per 100 cubic feet, as per statement below :—

Stone.

	₹	a.	p.
Cost at river bank	3	0	0
Carriage by boat to Theyráj	15	0	0
Loading, unloading, and incidental charges	2	0	0
Cost of rough stone per 100 cubic feet	20	0	0

67. Brick earth can probably be got near the site of the works, and the cost of first class bricks may be estimated as follows :—

Bricks.

	₹	a.	p.
Moulding, per 1,000	2	0	0
Fuel, „	6	0	0
Loading and unloading	1	8	0
Stacking	0	8	0
Land and kiln	1	0	0
Firing	1	0	0
TOTAL	12	0	0

Outturn 750; rate per 1,000 = $\frac{4}{3} \times 12$ = ₹16 per 1,000.

68. Kunkur has been found at several places in the bed of the Ravi, and it was stated by Mr. Palmer to be of first rate quality for lime in page 16 of the Report of Sidhnai Canal Project of 1875.

Lime.

The cost of kunkur lime is estimated as follows :—

Kunkur to be dug in Ravi and in District.

	₹	a.	p.
Digging 100 cubic feet	4	0	0
Average lead	5	0	0
Charcoal 10½ maunds, 100 cubic feet	10	8	0
Loading and unloading, and firing, 100 cubic feet	1	8	0
Lime grinding	2	0	0
Land and kilns	1	0	0
Total for outturn 60 cubic feet	24	0	0
Rate per 100 cubic feet	40	0	0

69. Deodár can be brought down the Ravi and delivered on the works at an average rate of ₹2 a cubic foot.

Timber.

70. In this estimate it has been considered sufficient to estimate for kunkur lime being used "neat." Should it afterwards be considered advisable to use soorkhee, there will be a saving.

Soorkhee not to be used.

71. There is little or no labour available for the works at present in the part of the country where the canal goes, and the rates for imported labour will be high.

Labour.

Rates for Works.

72. The earth-work rates are very little in excess of those in force on the Lower Sutlej Chenab Division, and have been based on those in that Division. The soil throughout is hard and dry, and will not be very easy to excavate.

Earth-work.

73. Concrete will be made from hard brick ballast broken to from 1″ to ¾″, and the materials will be in the proportions noted in the following estimate of the cost :—

Concrete.

	₹	a.	p.
Ballast, 120 cubic feet, at ₹10	12	0	0
Lime, 30 cubic feet, at ₹40	12	0	0
Labour, ramming, &c.	5	0	0
Incidental charges	1	0	0
TOTAL	30	0	0

Brick-work.

74. It is proposed to build all the works of brick masonry, stone only being used for pitching at head works.

On account of the high cost of kunkur lime and bricks, the cost of brick-work is higher than in most places, and the following estimate shows how the cost has been arrived at :—

Rate for brick-work.

	R	a.	p.
1,400 bricks, at R16	22	0	0
25 cubic feet lime, at R40	10	0	0
Labour	5	0	0
TOTAL	37	0	0

Pitching.

75. Cost of rubble masonry and pitching laid dry—

	R	a.	p.
125 cubic feet stone	25	0	0
Labour in laying	5	0	0
TOTAL	30	0	0

Centering.

76. It is proposed to use earthen centerings for all the arches, as they have been successfully used on the Sirhind Canal for larger spans than are used on this canal, and a suitable lump sum has been entered for centerings in each estimate.

Financial prospects of the Project.

Water-rates.

77. In paragraphs 18 to 22 the water-rates applicable to this canal have been discussed, and it does not seem probable that they can be increased at present. Of the 48,000 acres to be irrigated by this canal, 40,000 will be Government waste land at R1-8-0 per acre, and the remaining 8,000 at 8 annas per acre. The proportion of land at 8 annas is therefore $\frac{1}{6}$th of the whole.

Direct income.

78. The direct income during construction would then be as shown in Appendix No. 9 A., and the subsequent income as in the following statement :—

	R	a.	p.	R
40,000 acres at	1	8	0	60,000
8,000 „ „	0	8	0	4,000
Net income				64,000

Maintenance.

79. If the "chher" system is adopted, as would be the case with these rates, there will be no cash charge for maintenance.

Profit.

80. The total expenditure on this project, as shown in the general abstract of the estimate, is R6,73,488, and deducting R9,000 as cost of establishment a net income of R55,000 gives a return of 8·16 per cent.

Time for which the Sidhnai Canal Division is required.

81. It is proposed to complete all the masonry works and half of the earth-work of the canal by the end of 1885, and afterwards extend the canal and distributaries as irrigation increases. It will therefore only be necessary to have a Construction Division till the end of 1885-86, after which the remaining construction, together with the revenue work, could be carried out in connection with the Lower Sutlej and Chenab Division.

L. F. MACLEAN, C.E.,

Executive Engineer,

Sidhnai Canal Division.

Examined and approved.

R. D. BAYLEY,

Superintendent of Works, Derajat Circle.

SIDHNAI CANAL.

ESTIMATE No. 1.

(1) Head Works.

A. PRELIMINARY.—*Abstract of Cost.*

Quantity.	DESCRIPTION OF WORK.	RATE. At	RATE. Per	Amount.	TOTAL.
	I.—WORKS.	R		R	R
	1. Head Works.				
	A. Preliminary surveys, say	...	...	300	300
	Add contingencies at 5 per cent.	...	...	...	15
	TOTAL	...	...	...	315

ESTIMATE No. 2.

(1) Head Works.

C. WORKS.—*Abstract of Cost.*

Quantity.	DESCRIPTION OF WORK.	RATE. At	RATE. Per	Amount.	TOTAL.
	Regulator.	R		R	R
134,535 c. ft.	Excavation in foundation	8	1,000	1,076·28	
230 „	Well-sinking	3	ft.	690·00	
23 No.	Well-curbs	40	each	920·00	
8,680 c. ft.	Pacca masonry in wells	40	100	3,472·00	
3,680 „	Concrete in wells	30	„	1,104·00	
5,802 „	Concrete in foundations	30	„	1,740·60	
22,256·5 „	Pacca masonry	37	„	8,234·90	
4 sets	Centerings	250	each	1,000·00	
3,252 c. ft.	Arching	40	100	1,300·80	
3,320 „	Pitching	30	„	996·00	
1,500 „	Road-metalling	10	„	150·00	
370 „	Gates	2	each	740·00	
...	Iron pipes for drains	...	...	60·00	
...	Lifting gear for gates	...	...	150·00	
50 days	Pumping	30	day	1,500·00	
	Add contingencies at 5 per cent.	...	...	...	23,134·58 1,156·72
	TOTAL	...	...	...	24,291·30

ESTIMATE No. 3.

(1) Head Works.

C. WORKS.—*Abstract of Cost.*

Quantity.	DESCRIPTION OF WORK.	RATE. At	RATE. Per	Amount.	TOTAL.
	Weir Wall.	R		R	R
291,600 c. ft.	Excavation in foundation	8	1,000	2,332·80	
60 ft.	Well-sinking	3	ft.	180·00	
6 No.	Well-curbs	40	each	240·00	
1,950 c. ft.	Masonry in wells	40	100	780·00	
900 „	Concrete in wells	30	„	270·00	
14,600 „	Concrete in foundation	30	„	4,380·00	
22,315 „	Pacca masonry	37	„	8,267·65	
40,750 „	Stone pitching	30	„	12,225·00	
50 days.	Pumping	30	day	1,500·00	
	Add contingencies at 5 per cent.	...	...	...	30,175·45 1,508·77
	TOTAL	...	...	...	31,684·22

Estimate No. 4.

(1) *Head Works.*

K. Buildings.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	1st Class Choki.	R		R	R
4,377·75 c. ft.	Excavation in foundation	5	1,000	21·88	
4,377·75 „	Mud masonry in do.	5	100	218·88	
15,192·88 „	Mud masonry in superstructure	5	„	759·64	
1,691·12 „	Pacca masonry	37	„	625·71	
2,073·75 „	Sand filling	1	„	20·74	
2,073·75 „	Concrete floor	30	„	622·12	
332·40 „	Wood-work	2	ft.	664·80	
396·00 ft.	Doors, windows, and sky-lights	1	„	396·00	
3,006 1 ft.	Flat roofs	10	1 ft.	300·60	
4 No.	Punkhas	15	each	60·00	
4 „	Shelves	10	„	40·00	
					3,730·37
	Add contingencies at 5 per cent.	...	...	...	186·51
	Total	...	...	...	3,916·88
	Add for out-houses	...	...	...	542·49
	Total	...	...	...	4,459·37

Estimate No. 5.

(2) *Main Canal and Branches.*

Main Line.

A. Preliminary.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	I.—Works.	R		R	R
	2. Main Canal.				
40 miles	Surveying	15	mile	600	
20 „	Bench-marks	3	each	60	
					660
	Add contingencies at 5 per cent.	...	...	...	33
	Total	...	...	...	693

Estimate No. 6.

(2). *Main Canal and Branches.*

Main Line.

B. Land.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
		R		R	R
422·4 acres	Land	50	acre	21,120	
					21,120
	Contingencies at 5 per cent.	...	...	...	1,056
	Total	...	...	...	22,176

Estimate No. 7.

(2) *Main Canal and Branches.*

Main Line.

D. Regulators.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	At Mile 33. See para. 58, and Plan No. 8.	R		R	R
20,400 c. ft.	Excavation of foundation and filling in	8	1,000	163·20	
168·75 „	Concrete over arches	30	100	50·62	
6,827·55 „	Masonry	37	„	2,526·19	
480 „	Arching	40	„	192·00	
61 No.	Groove stones	1·8	each	91·50	
86·40 ft.	Gates	2	ft.	172·80	
675 c. ft.	Road-metalling	10	100	67·50	
21,570 „	Road approaches	5	1,000	107·85	
					3,371·66
	Contingencies at 5 per cent.	...	...	...	168·58
	Total	...	...	...	3,540·24

Estimate No. 8.

(2) *Main Canal and Branches.*

Main Line.

G. Bridges.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	At R. D. 12,000 ft. See para. 58, and Plan No. 6.	R		R	R
41,734 c. ft.	Excavation in foundation	8	1,000	333·87	
2,979 „	Concrete in foundation	30	100	893·70	
13,531·82 „	Masonry	37	„	5,006·77	
3,496 „	Arching	40	„	1,398·40	
1,980 „	Road-metals	10	„	198·00	
3 No.	Centerings	250	each	750·00	
					8,580·74
	Add contingencies at 5 per cent.	...	...	...	492·03
	Total	...	...	...	9,009·77

Estimate No. 9.

(2). *Main Canal and Branches.*

Main Line.

G. Bridges.

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	At R. D. 44,000 feet, see para. 58 and plan No. 7.	R		R	R
7,414·5 c. ft.	Excavation in foundation	8	1,000	59·55	
2,619·0 „	Concrete	30	100	785·70	
14,398·0 „	Pacca masonry	37	100	5,327·26	
3,462·75 „	Arching	40	100	1,385·10	
3 No.	Centering	250	each	750·00	
4 maunds.	Iron-work	15	Md.	60·00	
1,875 c. ft.	Road-metal	10	100	187·50	
66,585 „	Road approaches	5	1,000	331·92	
					8,887·03
	Add contingencies at 5 per cent.	...	...	.....	444·35
	Total	...	...	.....	9,331·38

Estimate No. 10.

(2). *Main Canal and Branches.*

Main Line.

K. Buildings.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	See para. 61 of Report.	₹		₹	₹
3,127·50 c. ft.	Excavation in foundation	5	1,000	15·63	
13,655·88 „	Mud masonry	5	100	682·79	
1,416·00 „	Pacca masonry	37	100	523·92	
1,417·50 „	Sand filling	1	100	14·17	
1,417·50 „	Concrete flooring	30	100	425·25	
231·16 ft.	Wood-work	2	ft.	462·32	
1,890 s. ft.	Mud roof	12-8	100	236·25	
234·00 „	Doors and windows	1	ft.	234·00	
2 No.	Punkhas	15	each	30·00	
2 sets	Shelves	10	„	20·00	
	Add contingencies at 5 per cent.	...	...	.....	2,644·33 132.21
	Total	...	...	.....	2,776·54
	Out-houses $\frac{2}{3}$ × 583	...	...	.....	388·66
	GRAND TOTAL	...	...	.....	3,165·20
	Add for 3 more	...	...	.....	9,495·60
	Total for 4 chaukís	...	...	.....	12,660·80

Estimate No. 11.

(2). *Main Canal and Branches.*

Main Line.

L. Earth-Work.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	Channel Excavation.	₹		₹	₹
38,213,050 c. ft.	Earth-work	5	1,000	1,91,065·25	
	Add contingencies at 5 per cent.	...	...	...	1,91,065·25 9,553·26
	Total	...	...	.....	2,00,618·51

Estimate No. 12.

(2). *Main Canal and Branches.*

Main Line.

M. Plantations.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
		₹		₹	₹
39 miles	Plantations	200	mile	7,800	
					7,800
	Total	...	...	.....	7,800

Estimate No. 13.

(2). *Main Canal and Branches.*

Main Line.

O. Miscellaneous.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	See para. 39 of Report.	₹		₹	₹
6,000,000 sq. ft.	Cost of experiments, say	...	...	1,500	
	Clearing jungle	...	...	3,000	
					4,500
	Total	...	...	.....	4,500

Estimate No. 14.

(2). *Main Canal and Branches.*

Main Line.

P. Maintenance.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
		₹		₹	₹
39 miles	Canal banks	200	mile	7,800	
	Cost of buildings	5	100 for 3 years	2,567·89	
					10,367·89
	Total	...	...	.....	10,367·89

Estimate No. 15.

(3). *Distributaries.*

A. Preliminary.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	I. Works.				
	3. Distributaries.	₹		₹	₹
35 miles	Surveying	10	mile	350	
20 do.	Bench-marks	3	each	60	
					410
	Add contingencies at 5 per cent.	...	...	.....	21
	Total	...	...	.....	431

Estimate No. 16.

(3). *Distributaries.*

C. Works.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	See para. 49 of Report.	R		R	R
42 miles	Distributaries Bridges	500	mile	21,000	
					21,000
	Add contingencies at 5 per cent.	...	...	.....	1,050
	Total	...	...	.....	22,050

Estimate No. 17.

(3). *Distributaries.*

C. Works.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	Head for Distributary No. I, see plan No. 8.	R		R	R
26,700 c. ft.	Excavation in foundation	8	1,000	213·60	
40·50 ,,	Concrete over arches	30	100	12·15	
7,649·00 ,,	Masonry	37	100	2,830·13	
494·00 ,,	Arching	40	100	197·60	
64 in No.	Grooving stones	1-8-0	ft.	96·00	
117·60 ft.	Gates	2	,,	235·20	
400·00 c. ft.	Road-metalling	10	100	40·00	
					3,624·68
	Add contingencies at 5 per cent.	...	...	.....	181·23
	Total	...	...	.....	3,805·91

Estimate No. 18.

(3). *Distributaries.*

C. Works.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	Head for Distributary No. II.	R		R	R
	Regulator as per Head of Distributary No. III, say	...	...	3,000	
					3,000
	Total	...	...	.....	3,000

Estimate No. 19.

(3). *Distributaries.*

C. Works.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	Head for Distributary No. III. See plan No. 8.	R		R	R
18,640 c. ft.	Excavation of foundation and filling in	8	1,000	149·12	
112·5 ,,	Concrete over arches	30	100	33·75	
6,084·60 ,,	Masonry	37	100	2,251·30	
360·00 ,,	Arching	40	100	144·00	
61 in No.	Groove stone	1-8	ft.	91·50	
86·4	Gates	2	ft.	172·80	
675·00	Road-metalling	10	100	67·50	
					2,909·97
	Add contingencies at 5 per cent.	...	...		145·49
	Total	...	...		3,055·46

Estimate No. 20.

(3). *Distributaries.*

L. Earth-Work.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	See paragraph 49 of Report.	R		R	R
42 miles	Distributaries	1,700	mile	71,400	
38 ,,	Minor Distributaries	1,500	,,	57,000	
					1,28,400
	Add contingencies at 5 per cent.	...	...		6,420
	Total	...	...		1,34,820

Estimate No. 21.

(4). *Drainage and Protective Works.*

A. Preliminary.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	I. Works.	R		R	R
	4. Drainage and Protective Works.				
	Preliminary surveys, say	...	...	.....	
					100
	Add contingencies at 5 per cent.	...	...	.....	5
	Total	...	...		105

ESTIMATE No. 22.

(4). *Drainage and Preliminary Works.*

L. EARTH-WORK.—*Abstract of Cost.*

Quantity.	Description of Work.	Rate. At	Rate. Per	Amount.	Total.
	See paragraph 23 of Report.	R		R	R
332,460 c. ft.	Earth-Work	3-8	1,000	1,163·61	1,163·61
	Add contingencies at 5 per cent.	...	...	......	58·18
	TOTAL	...	...	......	1,221·79

General Abstract of Estimate for the Sidhnai Canal.

Heads of Classification.	Head Works.	Main Lines.	Total.
A. DIRECT CHARGES.			
I. WORKS.	R	R	R
(1). HEAD WORKS.			
A. Preliminary	315·00		
C. Works	1,30,975·00		
K. Buildings	4,159·37		
TOTAL	1,35,749·00	...	1,35,745·00
(2). MAIN CANAL AND BRANCHES.			
A. Preliminary Expenses	...	693·00	
B. Land	...	22,176·00	
D. Regulators	...	3,540·24	
G. Bridges	...	18,341·15	
K. Buildings	...	12,660·80	
L. Earth-work	...	2,00,618·51	
M. Plantations	...	7,800·00	
O. Miscellaneous	...	4,500·00	
P. Maintenance	...	10,367·89	
TOTAL	...	2,80,697·59	2,80,697·59
(3) DISTRIBUTARIES.			
A. Preliminary	...	431·00	
C. Works	...	31,911·37	
L. Earth-work	...	1,34,820·00	
TOTAL	...	1,67,162·37	1,67,162·37
(4) DRAINAGE AND PROTECTIVE WORKS.			
A. Preliminary	...	105·00	
L: Earth-work	...	1,221·79	
TOTAL	...	1,326·79	1,326·79
TOTAL WORKS	1,35.749·00	4,49,186·75	5,84,936·64
II. ESTABLISHMENT	...	...	1,46,240·00
III. TOOLS AND PLANT. (12). MISCELLANEOUS (13). REPAIRS AND CARRIAGE } at 3 per cent.	...	...	17,550·00
TOTAL A, DIRECT CHARGES	...	...	7,48,727·00
B. INDIRECT CHARGES.			
(23). CAPITALISATION OF ABATEMENT OF LAND REVENUE	...	...	5,280·00
(24). LOSS BY EXCHANGE	...	...	...
(25). LEAVE AND PENSION ALLOWANCES, 14 PER CENT. OF ESTABLISHMENT	...	...	20,473·00
VII. Simple interest on Capital Outlay, see Appendix No. 9	...	...	*Nil.*
TOTAL B, INDIRECT CHARGES	...	...	25,753·00
GRAND TOTAL	...	...	7,74,480·00

Appendix No. 1.

Table of Works.

Distance from head in miles of 5,000 feet. Mile.	Distance from head in miles of 5,000 feet. Feet.	Name of Work.	Width. Land to be taken up.	Width. Bottom of channel.	Slope of bed. 1 in.	Slope of bed. Per 1,000.	Depth in feet.	Mean velocity.	Discharge in cubic feet per second.	Regulator or Escape. Number.	Regulator or Escape. Span.	Bridge Arches. Number.	Bridge Arches. Span.	Bridge Arches. Width between parapets.	Reduced level of bed.	Remarks.
		Weir across Ravi, length 770 feet	...	...	...	...	...	...	...	...	...	...	...	...	...	
		Regulator	340	80	8,000	0·125	5	1·847	800	8	10	4	22·5	12	454·50	
		First class bungalow	...	...	...	...	...	...	...	...	...	...	...	...	...	
2	2,000	Bridge over Sarai Sidhu and Talamba road	...	...	...	...	...	...	...	...	...	4	20	17	453·0	
10	4,000	Bridge over Sarai Sidhu and Kabírwála road	...	...	...	...	...	...	...	...	...	3	24·33	17	...	
11	1,000		...	...	...	...	...	...	...	...	...	...	...	...	...	Distributary No. 1 takes off.
11	2,000	Canal	...	58	5,886	0·174	4·5	1·987	556	...	...	...	...	...	447·32	
12	...	Second class bungalow at Ráepur	...	...	...	...	...	...	...	...	...	...	...	...	...	
22	...	Second class bungalow at Kot Búta	...	...	...	...	...	...	...	...	...	...	...	...	...	
25	...		...	...	...	...	...	...	...	...	...	...	...	...	...	Distributary No. 2 takes off.
25	1,000	Canal	...	46	5,886	0·174	4·0	1·80	363	...	...	...	...	...	435·32	
33	...	Bridge and regulator	...	...	...	...	...	...	...	...	...	4	5	17	...	Distributary No. 3 takes off.
33	1,000	Canal	...	20	5,000	0·20	4·0	1·768	1·70	...	...	...	...	...	428·33	
39	...	Second class bungalow, Ráshída	...	...	...	...	...	...	...	...	...	...	...	...	...	
39	...		...	...	...	...	...	...	...	...	...	...	...	...	...	Distributary No. 4 takes off.
		Second class bungalow at Kadurpur Ráwan	...	...	...	...	...	...	...	...	...	...	...	...	...	Distributary No. III.

Appendix No. 2.

Description.	Area commanded in square miles.	Proportionate discharges of distributaries.	Balance of water in canal.	Calculated discharges.	Depth of water	Bed width.	Hydraulic mean depth.	Slope of Bed per thousand.	Velocity.	C.	Remarks.
Canal at Head	...	...	800	785·1	5′	80	4·51	0·125	1·847	0·778	Exact discharge = 785·1.
Minor distributaries Nos. 1 and 2.	...	...	...	...	...	...	...	...	...	...	
Canal at 56,000 above distributary No. 1.	...	...	714	713·78	5′	73	4·45	0·125	1·835	0·776	75′ = average width from 4,000 to 56,000.
Distributary No. 1	55	158	...	154·00	3·5′	24	2·44	0·20	1·70	0·700	
Canal at 56,000 below distributary No. 1.	...	...	556	558·83	4·5	58	3·97	0·174	1·987	0·756	
Minor distributaries Nos. 3, 4, 5.	27	78	...	...	...	...	..	...	...	...	Distributaries take off at 75,000 and 95,000, average bed width 58,000 to 100,000 = 55′.
Canal above distributary No. 2 at 125,000.	...	...	478	481·4	4·5	50	3·91	0·174	1·941	0·752	Average bed, 100,000 to 125 = 51′.
Distributary No. 2	40	115	...	114·2	3·5	17	2·66	0·20	1·60	0·690	
Canal below distributary No. 2 at 125,000.	...	...	363	362	4′	46	3·49	0·174	1·81	0·735	
Minor distributary No. 6	8	23	...	...	...	...	...	...	...	...	
Canal above distributary No. 3 at 165,000.	...	..	340	340	4	43	3·48	0·174	1·80	0·735	Average bed 125,000 to 165,000 = 44·5, say 45′.
Distributary No. 3	59	170	..	169·7	4	20	3·06	0·20	1·768	0·714	
Canal below distributary No. 3 at 165,000.	59	170	170	169·7	4	20	...	0·20	1·768	0·714	Distributary No. 4 has a discharge of 92 c. ft.
Total	278	800	...	...	...	...	..	...	...	...	

Appendix No. 3.

Discharges of Ravi at Baghdád, calculated from Cross Section taken by Mr. Maunsell on 19th December 1882.

Reading on Gauge.	A. Area of Cross Section.	P. Wetted perimeter.	R. Hydraulic mean depth.	C. Co-efficient of mean velocity.	Q. Discharge in cubic feet per second.	V. Velocity in feet per second.
0·5	42·00					
1·0	84·75	86·75	0·977	0·513	39·22	0·460
1·5	129·25	89·00	1·451	0·574	84·96	0·634
2·0	175·75	92·25	1·905	0·636	140·55	0·799
2·5	225·00	95·00	2·380	0·636	201·31	0·895
3·0	275·50	142·25	1·937	0·636	222·10	0·806
3·5	364·50	210·00	1·735	0·631	276·06	0·759
4·0	498·75	272·25	1·832	0·627	383·86	0·770
4·5	446·75	353·00	1·832	0·649	511·53	0·790
5·0	838·75	388·25	2·160	0·653	703·10	0·839
5·5	1032·75	389·50	2·651	0·684	1046·61	1·103
6·0	1227·75	390·75	3·142	0·715	1416·70	1·153
6·5	1421·75	393·00	3·617	0·739	1817·28	1·278
7·0	1617·75	391·00	4·101	0·763	2254·90	1·394
7·5	1813·75	392·00	4·626	0·782	2782·00	1·533
8·0	2011·00	398·00	5·053	0·801	3305·40	1·642
8·5	2208·00	400·00	5·520	0·815	3870·52	1·752
9·0	2408·00	402·00	5·990	0·830	4465·20	1·854
9·5	2607·00	404·90	6·452	0·842	5093·60	1·954
10·0	2808·00	406·00	6·916	0·855	5763·70	2·053
10·5	3008·00	408·00	7·372	0·865	6453·80	2·145
11·0	3210·00	410·00	7·830	0·876	7183·00	2·238
11·5	3411·00	412·00	8·279	0·885	7916·17	2·318
12·0	3615·00	414·00	8·731	0·894	8717·30	2·411
12·5	3818·00	416·00	9·177	0·902	9481·48	2·483
13·0	4022·00	418·00	9·620	0·910	10362·50	2·576
13·5	4226·00	420·00	10·001	0·917	11136·00	2·647
14·0	4431·25	422·00	10·500	0·924	12111·80	2·733
14·5	4608·25	424·00	10·863	0·930	12868·00	2·793
15·0	4842·25	426·00	11·366	0·937	13963·80	2·884
15·5	5047·75	428·00	11·793	0·944	14931·86	2·957

Appendix No. 4.

Discharges of Ravi at Baghdál, calculated from Gauge Registers.

Month.	1876.		1876.		1877.		1878.		1879.		1880.		1881.		1882.		1883.	
	Average reading on Gauge.	Approximate discharge.	Average reading on Gauge.	Approximate discharge.	Average reading on Gauge.	Approximate discharge.	Average reading on Gauge.	Approximate discharge.	Average reading on Gauge.	Approximate discharge.	Average reading on Gauge.	Approximate discharge.	Average reading on Gauge.	Approximate discharge.	Average reading on Gauge.	Approximate discharge.	Average reading on Gauge.	Approximate discharge.
January	1·77	105	6·33	1,680	4·79	630	8·12	3,463	2·44	195	1·70	100	...	...	3·27	265	1·60	92
February	...	...	6·51	1,825	8·21	3,578	8·46	3,855	2·03	145	3·65	337	...	...	6·60	1,827	4·21	440
March	4·47	503	6·71	1,985	8·84	4,275	8·72	4,140	3·33	257	3·37	250	6·10	1,500	5·90	1,330	3·73	325
April	4·55	524	8·21	3,642	8·78	4,200	9·20	4,709	3·23	246	3·26	250	7·12	2,365	7·86	3,137	3·44	271
May	5·78	1,253	8·92	4,364	9·65	5,275	9·54	5,145	3·70	316	4·52	527	8·27	3,605	7·75	3,043	5·68	1·176
June	5·16	815	9·39	4,955	9·66	5,380	9·47	5,055	4·43	500	4·98	695	9·33	4,805	8·64	4,040		
July	9·08	4,560	11·33	7,658	9·81	5,550	10·34	6,240	10·64	6,658	12·12	8,900	11·13	7,327	10·67	6,736		
August	13·27	10,765	14·42	12,700	8·76	4,170	13·35	10,905	12·42	9,385	10·34	6,240	12·80	9,205	11·84	8,470		
September	11·60	8,100	10·00	5,763	8·03	3,320	11·21	7,500	10·00	5,763	8·10	3,430	9·90	5,630	11·26	7,546		
October	10·77	6,847	7·56	2,846	4·90	663	6·45	1,775	5·41	983	4·96	695	6·60	1,827	6·52	1,825		
November	7·90	3,205	5·90	1,330	3·10	230	4·02	385	3·00	222	3·02	225	4·50	511	3·84	360		
December	6·38	1,721	4·56	545	8·90	4,350	3·08	230	1·99	139	2·28	175	3·00	222	2·72	200		

Appendix No. 5.

Discharge of Ravi at head of canal over proposed weir, slope of river bed = 0·083 per 1,000.

D.	Area of cross section.	Wetted perimeter.	Hydraulic mean depth.	Co-efficient of mean velocity.	Discharges in cubic feet per second.	Velocity in feet per second.
0·5	371·25	744·0	0 498	0·4103	98 22	0·264
1·0	743·50	746·5	0·995	0·5178	352·15	0·471
1·5	1116·50	749·0	1·490	0·6132	763·94	0·684
2 0	1490·00	751 5	1 982	0·6342	1216·00	0·816
2·5	1864·00	753·5	2·475	0 676	1809 20	0·970
3·0	2238·00	755·5	2·962	0·7058	2481·84	1·10
3·5	2613·75	759·5	3·450	0·7309	3239·30	1·23
4·0	2990·00	759·5	3 936	0 7562	4095·35	1·36
4·5	3367·25	761·5	4 421	0·7768	5020·95	1·49
5 0	3745·50	763·5	4·906	0·7954	6023·55	1·60
5·5	41224·75	766·3	5·382	0·8106	6920·00	1·67
6 0	4504·75	768·6	5·861	0·8255	8218·10	1·82
6·5	4885 75	771·3	6·334	0·8395	9421·20	1·92
7·0	5266·25	773·5	6·808	0·8519	1068·50	2·02
7·5	5649·00	775·0	7·289	0 8626	12009·50	2·12
8·0	6044·00	777·5	7·773	0·8731	13399·50	2·22
8·5	6435·00	778·5	8 304	0·8858	14998·00	2·33

The level of crest of weir is 454·50, the same as level of canal bed.

Appendix No. 6.

Number of acres irrigated per cubic foot on Punjab Canals.

Canals.	1878-79.			1879-80.			1880-81.			Mean for 3 years.	Remarks.
	Rabi.	Kharif.	Whole year.	Rabi.	Kharif.	Whole year.	Rabi.	Kharif.	Whole year.		
Western Jumna Canal . .	91·0	103·0	194·0	72·6	89·1	161·7	85·2	71·7	156·9	170·8	*N B.*—The duty assumed for Sidhnai Canal is 60 acres.
Bári Doáb Canal	109·6	63·95	173·55	110 62	62·37	180·99	146·9	56·0	202·9	185·8	
Upper Sutlej Canals .	115·8	45·7	90·4	162·8	31·4	69·2	165·4	62·7	138·7	99·4	

Appendix No. 7.

Schedule of Rates used in the Estimates.

Description of Work.	Rate. At	Rate. Per	Remarks.
	₹ a. p.		
Excavation mile . . Distributaries . . .	1,700 0 0	mile.	See para. 45 of Report.
Do. . . Do. . . .	1,500 0 0	,,	
Do. and filling in Foundations . . .	8 0 0	1,000	
Do. . . Main Canal . . .	5 0 0	,,	
Do. . . Drains . . .	3 8 0	,,	
Concrete	30 0 0	100 cubic feet.	
Brick-work	37 0 0	,,	
Arch-work	40 0 0	,,	
Metalling	10 0 0	,,	
Pitching	30 0 0	,,	
Wood-work	2 0 0	cubic foot.	
Cast Iron-work	12 0 0	maund.	
Kacha Brick-work	5 0 0	100 cubic feet.	
Flooring concrete	30 0 0	,,	
Doors and Windows	1 0 0	s. feet.	
Punkhas	15 0 0	each.	
Land	50 0 0	acre.	

Appendix No. 8.

Detail of Establishment proposed during construction.

Description.	Salary.	No.	Cost. Per month.	Cost. Per year.	Remarks.
Engineer Establishment.	₹		₹	₹	
Executive Engineer	600	1	600	7,200	
Assistant do.	400	1	400	4,800	
Lower subordinates	40	4	160	1,920	
Artificers	25	4	100	1,200	
Office Establishment.					
Accountant	132	1	132	1,584	
Clerk	55	1	55	660	
Do.	45	1	45	540	
Do.	35	1	35	420	
Draftsman	50	1	50	600	
Munshi	25	1	25	300	
Do.	20	2	40	480	
Hospital Assistant	38	1	38	456	
Chaprasís	6	3	18	216	
Sowárs	20	2	40	480	
Tindals	7	4	28	336	
Khalássís	6	20	120	1,440	
Dák runners	6	3	18	216	
Temporary Establishment	...	...	75	900	
Travelling allowance and contingencies . .	...	...	300	3,600	
Total .	...	...	2,279	27,348	

[Appendices Nos. 9, 9 A, 10, 11 omitted.]

No. 74 C., dated Simla, 29th June 1883.

From—F. C. Channing, Esq., Senior Secretary to Financial Commissioner, Punjab,
To—The Joint-Secretary to Government, Punjab, Public Works Department, Irrigation Branch.

I am directed to reply to your letter No. 2778 of 10th May.

2. The Officiating Financial Commissioner understands that there are only two points on which information is sought from this office as to the projected Sidhnai Canal—

A.—As to the areas and approximate distribution of Government waste and village lands respectively, included in the tract commanded by the canal as shown in the map which formed an enclosure of your letter, and which is herewith returned.

B.—As to the rates, which can be obtained from—

(1) Lands already granted or assessed to revenue.

(2) Lands which are still Government property.

3. On receipt of your letter the Officiating Financial Commissioner requested the Deputy Commissioner of Mooltan in this office letter No. 10 C. of 23rd May (copy herewith) to mark on the map received from your office the two classes of land, and, if possible, to also give their areas. From his reply, No. 394 of 2nd June (copy herewith), you will see that the Deputy Commissioner has not been able to give the areas, but he has roughly marked off the private and public lands on the map; to make the distribution clearer, Colonel Davies has had the Government land coloured with a wash of lake at the back; and he believes that you will now be able to have the approximate areas of each kind of land calculated in your office.

4. Turning to the second question, that of the rates to be levied, I am to premise that the Officiating Financial Commissioner understands that the works will be so designed as to give a very fairly regular supply of water for an Inundation Canal; that the command of the distribution of the water will be good; and that the soil is excellent: he has not either overlooked the fact that much of the land which will be commanded by the canal is near the city of Mooltan. He understands further that it is not intended to introduce the chher system, and that the chhers, or watercourses, will be cleared out by the Canal Department, and not, as in Montgomery, by the people.

5. In considering what rates should be levied the Officiating Financial Commissioner has examined the rates paid on other Inundation Canals. He finds that on the Upper Sutlej

Inundation Canals in Montgomery the average incidence of the fluctuating land revenue assessed in the form of varying crop rates, as stated in the last Irrigation Report, was:—

	₹	₹	a.	p.
Kharif	$1\frac{3}{16}$	= 1	12	9
Rabi	$0\frac{9}{16}$	= 0	14	5
TOTAL .	$1\frac{3}{16}$	= 1	3	2

The landowners pay, in addition to the above, the land revenue assessed at settlement, and also clear out the watercourses; the Canal Department clears out the canals and the main distributaries; the cost of the clearances effected by the people was formerly estimated at 12 annas per acre; but Colonel Davies understands that, owing to the extension of cultivation, it is now under 8 annas per acre.

6. In Mooltan District the canals are cleared by *chhers*; there is no direct canal rate, the canal lands are assessed as such, and the Canal Department receives credit for the whole revenue of simple canal lands and two-thirds of the revenue of canal, plus well-lands. All items being taken into consideration, the cost of canal irrigation in Mooltan, to the irrigators, was estimated last year at ₹1·51 per acre, against ₹1·76 and ₹1·71 in previous years, of which apparently about ten annas per acre was the cost of clearance. But no doubt the cost of irrigation, which is in this way composed partly of a fixed land revenue demand is apt to be somewhat low, as there are so many causes which tend to keep down a settlement jama.

7. The average incidence of water-rate on an Inundation Canal, especially in a tract of scanty rainfall like the Mooltan Division, must depend very largely on the proportion borne by kharif to rabi cultivation. On the Upper Sutlej Canals the proportions appear to be about $\frac{2}{3}$rds and $\frac{1}{3}$rd. For kharif cultivation a fairly high rate can be demanded, because the canals alone are sufficient to bring the crop to perfection; but for the rabi to be successful it must be watered from wells; this fact is recognised in the crop rates levied on the Montgomery Canals.

In Shahpur, where ₹2-8 per acre is taken, and on the Chenab Canal, where Mr. Lyall put the water-rate (to include also all land revenue except a grazing rate) at this sum, the rainfall is larger, and the necessity for auxiliary irrigation in the rabi is smaller.

8. Colonel Davies's conclusion from a consideration of the above facts is, that it would not be safe to estimate the income from water-rate in assessed estates at more than ₹2-8 per acre for the kharif and ₹1-8 for the rabi; and this estimate is based on the assumptions as to the manner in which clearances will be effected, which have been above noted. As a good deal of the cultivation will be close to the excellent market of Mooltan, the above rates will not, he thinks, be found excessive. He understands that in actual assessment differential crop rates will be imposed, which will, on the average, yield amounts per acre approximating to ₹2-8 and ₹1-8 in the kharif and rabi respectively.

9. It is necessary next to consider whether, it being assumed that the above rates will be taken in assessed estates, it will be possible to take somewhat higher rates on Government lands. But I am in the first place to point out that the Officiating Financial Commissioner does not think it probable that the Government will retain the proprietorship of these lands when they come under irrigation. He understands that the present policy of the Government would rather be in favour of putting up the lands for public competition with an option to the person acquiring them to buy or take on lease: and he believes that a large proportion of the lands now owned by Government in the area commanded by the canal would, when they became irrigable, be granted away or sold. The Irrigation Department would be entitled to claim credit to the canal for the enhanced value of the lands so disposed of, which had been caused by the construction of the canal, but a higher rate could not thereafter be claimed on the ground of the Government proprietorship. The only ground on which a higher rate could be claimed would be that the village lands were paying a fixed assessment, while these lands were free from it. But Colonel Davies holds that in all cases of grant or sale a light fixed assessment on the land in its grazing aspect would be imposed; and, although the village lands would be paying an assessment on their wells (in Mooltan there is practically no unirrigated cultivation) which the other lands would until the next settlement escape, yet on the other hand the grantees and purchasers of the new land should have to incur considerable expense in the construction of wells and the clearing of land. On the whole, therefore, the Officiating Financial Commissioner does not think that higher rates than those already noted can be expected from the Government lands.

No. 10 C., dated 23rd May 1883.

From—F. C. CHANNING, Esq., Senior Secretary to Financial Commissioner, Punjab,

To—The Deputy Commissioner, Mooltan.

I am directed to forward you a map received from the Irrigation Department showing the area commanded by the proposed canal from the Ravi, and to request that you will return it after indicating on it with approximate accuracy—

A—private lands included in assessed estates.

B—unassessed Government lands, *e.g.*, Bar waste. Probably the best way to do this will be to mark the Government lands by shaded lines.

2. If at the same time you are able to calculate the areas of the two classes of lands above noted, the Officiating Financial Commissioner will be obliged by your doing so; but if you cannot, you will state the fact of your inability.

3. A very early reply is requested: it should be addressed to Simla.

No. 394, dated 2nd June 1883.

From—E. O'BRIEN, Esq., Deputy Commissioner, Mooltan,

To—The Senior Secretary to Financial Commissioner, Punjab.

In reply to your No. 10 C., dated 23rd May, I have the honour to return the map with the private lands and unassessed Government lands marked off on it.

The Government lands are distinguished by shaded lines, a number, and the letter J for jungle. It has been found impossible to give the area of each class of land.

Despatch from the Government of India, to the EARL OF KIMBERLEY, Her Majesty's Secretary of State for India,—No. 30 P.W., dated 4th July 1884,

We have the honour to report that we have accorded provisional sanction in anticipation of the approval of Her Majesty's Government to an estimate, amounting to ₹7,74,480, of which ₹7,48,727 represent the direct, and ₹25,753 the indirect, charges for the construction, as a Productive Public Work, of an irrigation project from the Sidhnai reach of the river Ravi in the district of Mooltan in the Punjab. We have considered this course necessary to admit of the early completion of the work, the Government of the Punjab having stated in paragraph 2 of its letter No. 5045I., dated 22nd October 1883, that "construction will be vigorously prosecuted as soon as sanction is received."

2. The canal will command 300 square miles of excellent land, on which luxuriant crops are grown, wherever water is available. The average annual rainfall is, however, only 6 inches, and, at present, about one-fortieth of the area is irrigated from wells.

3. The canal is to discharge 800 cubic feet per second; and assuming the very moderate duty of 60 acres per cubic foot per second, it will irrigate 48,000 acres, or 25 per cent. of the area commanded.

4. The landholders of the district are eager for the canal, and the Deputy Commissioner of Mooltan considers that land will be freely taken up under it, not less than 6,000 to 8,000 acres being annually brought under cultivation until the full irrigable area is reached.

5. The rates of labour and material adopted in the estimate of the capital cost of the project are fair and reasonable, and the engineering designs being of the simplest description, call for no comment.

6. It is proposed to complete the whole of the masonry and half of the earthwork of the canal by the end of 1885. The canal, and its distributaries, will then be gradually extended, as irrigation increases, under the supervision of the establishment of the adjoining Canal Division. It is therefore hoped that irrigation will commence in 1884-85 and be fully developed in 1890-91, when the work will be finally completed.

7. The water rates have, with the approval of the Financial Commissioner of the Punjab, been assumed at ₹2-8-0 per acre for the "kharif" and ₹1-8-0 per acre for the "rabi," during which season the canal irrigation will ordinarily have to be supplemented by a watering from wells.

8. The question of the employment of statute labour for the maintenance of the canal has not yet been finally decided. The Government of the Punjab has therefore submitted two

sets of financial statements, one showing the results expected without the aid of statute labour and the other withi . It will be observed from these statements that in the former case the canal is expected to yield a net return of ₹68,000, or 8·78 per cent. on the total capital outlay, and in the latter ₹55,000, or 7·1 per cent.

9. There being no reasonable doubt that, whichever system be eventually adopted for its maintenance, the project will prove sufficiently remunerative to allow of its being classed as a Productive Public Work, we have sanctioned it as a charge against the Productive Public Works grants, and solicit your Lordship's approval of our action in the matter.

10. The views of the Chief Engineer for Irrigation upon the project generally and the estimate of financial prospects framed by the Financial Commissioner, have been formally approved by His Honour the Lieutenant-Governor.

Despatch from the Secretary of State for India, to the Government of India,—No. 47 P. W., dated 28th August 1884.

Your Excellency's Public Works letter No. 30, dated 4th July 1884, transmits information respecting a projected irrigation work in the Punjab called the Sidhnai Canal Project, construction of which, as a Productive Public Work, has been sanctioned by your Government, subject to my confirmation.

2. It appears from the documents accompanying your letter that the canal, which is intended to command about 300 square miles of land, will, on a moderate computation, irrigate by 1890-91 about one-fourth of the area commanded, or about 48,000 acres, and taking the water-rates, as proposed by the Government of the Punjab, at ₹2-8 per acre, for "kharif," and ₹1-8 per acre for "rabi," a return of at least 7 per cent. on the capital outlay required, ₹7,74,480, is looked for. The engineering features of the proposed work are, you state, unusually simple, while much of the land to be irrigated lies in the immediate vicinity of the city of Mooltan, where there exists a good and steady demand for agricultural produce.

3. The financial results of operations on inundation canals in the Punjab are, as pointed out in my Public Works Despatch No. 45 of this day's date, respecting the Chenab Canal Project, of a distinctly encouraging nature, and the present scheme appears to be one which, on the information supplied by the Local Government, is likely to prove both directly and indirectly remunerative.

4. I sanction, therefore, the construction of the Sidhnai Canal in the Punjab from the Productive Public Works funds at disposal of your Government, the total capital outlay being fixed at ₹7,74,480, of which ₹7,48,727 represent direct, and ₹25,753 indirect charges.

5. With regard to the provisional sanction given by you to this estimate, I have to draw the attention of your Government to my remarks on this point in my Despatch No. 46 of this day's date, regarding the Lower Sohag and Para Canal in the Punjab.

DESCRIPTION OF THE HEAD WORKS OF THE SIDHNAI CANAL.

CHAPTER I.

Head Regulator.

Block Plan of Head Works.

Drawing No. I A is a block plan on a scale $\frac{1}{1000}$th of the Head Works of the Sidhnai Canal, from which the general arrangements may be seen.

Head Regulator.

2. The Head Regulator consists of four 60° arches, of 22·5 feet span, with jack piers in the centre, 2·5 feet thick, dividing the waterway into 8 spans of 10 feet, with 60° arches, springing from 6 feet above the floor.

Floor level.

3. The floor level is 454·50, *i.e.* one foot above the crest wall of Dam, and as the Dam is designed to hold up 7·5 feet water, 6·5 feet can be forced into the Canal, at all times when there is enough in the Ravi for the purpose, but the discharge of the Canal is only calculated for a depth of 6 feet.

Design, in general, of usual type.

4. There is nothing novel in the general design of the Regulator, and the drawing of the completed work shows all details; the only point in the design worthy of particular notice is the arrangement for lifting the gates, holding them up and letting them go.

Gates.

5. The gates are made of deodar wood, bound with iron, and work in cast iron grooves (see drawing).

Lifting, holding up, and letting go gear.

6. The lifting apparatus is a travelling crab winch, with two wheels working on a rail on the top of the parapet of the bridge, and one wheel on the roadway, the winding drum of the crab winch being so placed that the chain from it is vertically over the centre of the gate to be lifted, while on the roadway side there is a counterpoise to prevent the tension of the chain pulling the machine into the river.

Grooves for gates and planks.

7. There are two sets of grooves, the outer one being used for planks, and the inner one for the gates.

Use of planks and gates.

8. Planks are generally used for regulating the supply in the Canal, and the gates are intended for closing the Canal, when it is necessary to do so, by dropping the gates on to the floor where the pressure of water causes them to remain in that position.

Use of holding up and letting go gear.

9. The drawing of the "Holding up and Letting go Gear" shows how this is done, the gate being suspended at any height necessary. The catch pin is set free from the moveable lever by a blow with a hammer and the gate falls instantaneously.

Comparison with similar gear for Swat River Canal.

10. The Holding up and Letting go Gear has worked very well, and it was designed by the Executive Engineer on the same principle as the apparatus used on the Swat River Canal, the main difference being that on the Sidhnai Canal Regulator the catch pin and lever move in a horizontal plane round a vertical axis, while on the Swat River Canal apparatus they move in a vertical plane on a horizontal axis.

Working of planks.

11. The planks are worked by hooks in the ordinary way.

Commencement of construction.

12. The work was commenced in September 1884, as soon as the river had begun to fall and the bunds shown in drawing No. V had been constructed, and as there was no necessity for steam pumping, and as hard clay for the foundations was found throughout, the work progressed rapidly without any hitch and was practically finished in March 1885.

Final completion of works.

13. There was some delay in getting the Gates, "Holding up and Letting go Gear," and Crab Winch, completed, and these items of the work were not done till the end of May 1886, but during the season of 1885 it was found possible to work the Regulator with planks, as the Canal was not then open for irrigation, and only a little water was admitted to supply masonry works in progress, and to fest the banks.

Expenditure on Works and Savings.

14. The total expenditure on this work was ₹25,571, showing a slight saving on the sanctioned estimate.

CHAPTER II.

Needle Dam.

Necessity for dam and project provision for Head Works.

On account of the small amount of water in the Ravi at times when it is required for irrigation (as brought to notice in paragraph 13 of Executive Engineer's Report on the project of 1883) provision was made for works in the river to raise the water level at these times. The total provision for Head Works was ₹1,35,745, against which the following estimates have been sanctioned :—

	₹
Head Regulator, Sidhnai Canal	27,121
Needle Dam	1,02,022
Needle Lock	11,185
TOTAL .	1,40,328

The excess was provided for by the transfer of funds from other heads of the Project estimate.

Selection of design for dam.

2. In October 1883, steps were first taken to settle on a design for the dam, and in consequence of the French needle system seeming most suitable to the circumstances of the case, a design on this principle was prepared by the undersigned Executive Engineer and submitted for sanction.

3. In October 1883 a section of the river bed on the line of proposed dam was taken by means of boring machinery, and it was then found that, although 250 feet on the left bank, and 200 feet on right, gave a good clay foundation for the work at a reasonable depth below the top of proposed crest wall (see drawing No. I) the central portion of 390 feet was in sand of such a depth that to carry down the foundations to clay underneath would be very costly, and would necessitate the use of wells.

Section of Ravi in line of dam, showing deep sand in centre.

4. The problem then was, what sort of foundations should be adopted for the part of the dam over deep sand, and it was decided to adopt shallow concrete foundations for the piers, with concrete arches between them supporting the crest wall (see Drawing No. VII).

Design of foundations in deep sand.

5. In January 1884 on the occasion of Colonel R. Home's visit to Sidhnai it was also decided—

Programme of work for 1884.

(*a*) That the level of the crest wall of the dam be fixed at reduced level 453·5.

(*b*) That a trench be dug across the river in the line of dam to reduced level 44·00, as shown on cross sections of dam as actually constructed.

(*c*) That sheet piles, 10 feet long, be driven in this trench as shown on the plan of the dam as actually constructed, to act as a protection to the foundations of the pier, and also to prevent excessive percolation of water through the sand below, caused by the considerable difference of level of water above and below the dam.

(*d*) That, as soon as the piles were driven, the foundations of the piers be made with concrete, and the trench filled in with stiff clay, as the work proceeded.

(*e*) That the part of the dam in clay foundations, *i.e.* spans 1 to 11 and 29 to 32, should be left till next season.

(*f*) That each span be 20 feet.

(*g*) That the river should be contracted to 32 spans of 20 feet, with 3 feet thick piers, *i.e.* 733 feet between the side rivetments.

6. In order to allow of work being carried on when the Ravi began to flow, which was expected to be in February (the river having dried up on 1st December 1883) the central part of the trench, about 500 feet in length, was surrounded by a strong embankment and the spaces at each end between this embankment and the river banks were left open, so as to allow the river water to flow past, and for the convenience of work-people a temporary trestle bridge was constructed to connect this embankment with the left bank of the Ravi (see Drawing No. 2).

General arrangements for work, 1884.

7. About the 10th February the excavation of the trench was completed, and no pumping being required to keep the water down to reduced level 440·00, pile driving with ringing engines was in rapid progress, the piles being 10′ × 10″ × 2½″, with an iron shoe at the lower end, and protected from the blows of the wooden rams by an iron ring, which was removed as soon as the pile was driven to full depth. For sketch of ringing engine and ram (see Drawing No. 3).

Completion of trench excavation and pile driving.

8. The sheet piling to be driven in this trench consisted of two lines, 20 feet apart, parallel to the centre line of dam, with cross lines 7 feet apart, at intervals of 23 feet, to act as boxing for pier foundations, and this season's operations were confined to driving the longitudinal lines.

Position of piling driven in season 1884.

9. On the 6th February, the Bari Doab Canal was closed, and water arrived at the Dam on 18th idem, and although all the available hand pumps were used, water at once began to rise in the trench and could not be kept below reduced level 444·0.

Closure of Bari Doab Canal and results of water coming down Ravi.

10. The 12 H.P. steam engine and 10 inch Appold's centrifugal pump which were sent from Rupar could not be set at work till 27th February, when in a few hours the trench was unwatered and work was again started, but the same afternoon through the carelessness of the driver, the main shaft brasses ran hot and went to pieces, so that work was again stopped till 1st March, when new brasses were fitted.

Steam engine and pump.

11. From this time pile driving and clay filling into the trench went on satisfactorily till 20th March, when the Ravi suddenly rose, washed away the temporary bridge, burst through the embankments into the trench, and stopped all further operations for that season, the engine and pump being with great difficulty rescued, and taken to a position of safety on the right bank of the river.

Work stopped for season by flood in Ravi.

12. The work done during the season 1884, in addition to the excavation of trench, was as follows:—

Actual work done in season 1884.

Piles driven	700 No.
Clay filling in trench	14,554 cubic feet.

13. Work having been stopped for the season, nothing could be done till the Ravi fell, except completing the design and estimate for the Dam and collecting materials for the work. The former were completed and sanctioned by the Chief Engineer in October 1884 for ₹1,02,098, and as regards the latter bricks, concrete ballast, and lime were manufactured, so as to be in readiness for work in October, when the Ravi would fall.

Completion of design and estimate and manufacture of materials.

14. The only material which requires description here is the lime, which was made as follows:

Lime.

15. Pea kunkur, which abounds in many parts of the Multan District, was swept up, collected in bags, and carried by camels to the Head Works; it was there mixed with ⅕th part clay, moulded into bricks and burnt in circular kilns with layers of wood, and the bricks being thoroughly burnt were broken into pieces, about 3 inches or 4 inches cube, and ground by a 12 H.P. engine in two iron mortar pans, coupled to one shaft, and driven at a considerable speed.

Manufacture of kunkur lime.

16. The lime thus manufactured was very fine, and set under water in about one month, to nearly the hardness of an ordinary brick, and concrete which had been practically made under water was found to have thoroughly set a year afterwards.

Quality of lime.

17. The cost of the lime is as follows:—

Cost of lime.

	₹
Kunker	10
Fuel	5
Labor, burning, loading and unloading	4
Grinding, sifting, stacking	7
General Charges	1
TOTAL	27 per 100 cubic feet.

18. The design for the dam mentioned in paragraph 13 above, provided for concrete arches to support the crest wall, in the part on deep sand foundations for 400 feet in the centre, and also contained an arrangement by which the beams should float off during floods, and remain attached to their respective piers by chains till the flood subsided, when they could be placed in position again. It was also assumed that the tenacity of the mortar would give sufficient resistance to the pressure of the beams against the top foot of each pier.

Sanctioned design for dam.

19. A special report, showing the calculations according to which the dimensions of the main beams and needles have been fixed, is attached to this chapter.

Strength of beams and needles.

20. At first it was intended to use stone from Chiniot for the pitching of the dam, but after quarrying and carrying 750 cubic feet to the dam, it was found too expensive, costing ₹30 per 100 cubic feet in stacks at the Head Works, and as brick blocks of the description shown in Drawing No. IV, made of 12 bricks, 12″ + 6″ × 3″, cost only ₹27 per 100 cubic feet, laid in the work, the idea of getting more stone was abandoned.

Chiniot stone and brick block pitching.

21. Experience has shown that this sort of block is admirably suited for such pitching as is required on this dam, for it has successfully withstood all the severe tests to which it has been subjected up to the present, including the highest flood on record in the Ravi during August 1887.

Brick block pitching well suited for dam.

22. Monolithic clay blocks were also tried for pitching, and they were found cheaper, but useless on account of their low specific gravity, for in 1885 one span of pitching made from them was ripped up and washed away; their use was therefore discontinued.

Monolithic clay blocks rejected as a failure.

23. In the beginning of October 1884, the Ravi fell sufficiently to allow arrangements for commencing work on the dam being put in hand, by means of bunds and spurs on both banks, the stream was forced into the centre part of the channel, the parts of the dam in clay foundations were laid dry, and excavation was started as shown in drawing No. 5, the line ABCD being the centre line

Arrangements for work, season 1884-85.

of dam and corresponding with ABCD on drawing No. 2, referred to in paragraph 6 of this chapter.

Arrangements for work, season, 1884-85.

24. As long as the Ravi continued to flow, work was confined to the construction of spans 1 to 10 and 28 to 32, which fell within the trenches AB and CD, but when the flow ceased on 22nd December, steps were at once taken to open up the trench of last season, and to complete the whole of the dam.

Arrangement of bunds for construction, central portion of dam.

25. Drawing No. VI shows the general arrangements for enclosing the central part of the dam within embankments, similar to those described in paragraph 6 of this chapter, so that when spans 1 to 10 and 28 to 32 were completed, any water coming down the river might pass through the openings, without interfering with work in the central portion. The parts F L and GK were strongly protected with pitching blocks to prevent erosion.

State of work in beginning of January 1885.

26. In the beginning of January 1885, spans 1 to 10 were completed, and the waterway for the river cleared, but as the foundations only of spans 28 to 32 were put in that part could not be used for waterway. Meanwhile, in the central portion, rapid progress was being made in pile driving, clay filling, and concrete foundations.

Flood of 13th January 1885.

27. On 9th January Telegraphic notice was received that an extraordinary flood had passed Madhopur on the night of the 8th, and all labour was at once put on to strengthen the bunds and prepare for the coming flood, but the precautions were of no avail, as the flood arrived during the night of the 13th January, and in a short time breached the embankment at F. Next morning the water was passing over the tops of the completed piers with a velocity of at least 10 feet per second, the trench was filled with water, the embankments were breached in many places, and the engine and pump were almost entirely submerged.

Damage done by flood.

28. The damage done by the flood of the 13th January was very great, and although it only lasted about 24 hours, the river continued to flow about 4½ feet deep through the open spans during the rest of January, which made it difficult and costly to close the breaches in the embankments, and even when this had been done heavy pumping was necessary. The trench was also filled with about 3 feet of slush, which had to be removed before pile driving, concrete laying, &c., could be commenced in it again.

Flood of 10th February 1885.

29. The most severe flood of the season however arrived at Sidhnai on the morning of 10th February, and was passed through 9 spans of the dam, the 10th span being closed, to prevent scour along the face of the protective embankment FL. This time the bunds were not breached to any great extent, although water came in at the point K, and again flooded out the work.

Flood of 10th February 1885.

30. In the Progress Report of the Sidhnai Canal Division for February the passage of the flood through the 9 open spans is thus described—

"The velocity of the water could not be measured, but it must have been at least 16 feet per second. The down stream pitching stood this severe test without suffering any damage."

Concrete arches for crest wall not safe.

31. It may here be mentioned that since the commencement of construction of the dam, both the Superintending and Executive Engineers had been afraid that the plan of carrying the crest wall of the central spans on concrete arches would prove a dangerous expedient, and that it would be much safer to carry the whole foundations of the work in the central part down to one level of 440·0.

Danger to be anticipated from concrete arches for crest wall.

32. Drawing No. VII shows what was feared. Supposing the trench to have been filled with clay, the concrete arch AB constructed over the clay filling, and the whole of the superstructure, clay, filling and pitching completed, there was danger of a subsidence of the clay filling from below the crown of the arch along AB, and of a passage for water being then opened along such a line as AC. It was feared that the heading up of water against the dam would cause a rush of water under the arch, which could not be stopped, and which in addition to rendering the dam useless for a whole season, might undermine the piers and wreck the work.

Chief Engineer approves of concrete arches being abandoned.

33. The Chief Engineer on his visit to Sidhnai in February recognised this danger, and sanctioned the required change in the design, which is shown in the drawing of the work, as constructed.

Description of work done in March and beginning of April from Progress Report of Sidhnai Canal Division.

34. The following Extract from the Progress Report of the Sidhnai Canal Division for March 1885 shows how the dam was practically finished in the beginning of April 1885—

"The piling was completed early in the month, and every effort was made to complete the foundations rapidly, but very great difficulty was experienced in getting in the first 3 feet of concrete, on account of violent springs, which burst up all over the foundation at reduced level 440·0.

"The most difficult part of the work was the foundations of the crest wall in spans 11 to 15, and they were only got in by completing the rest of the piers and crest wall up to reduced level 453·50, and then moving the steam pump along the completed pitching to pump from these 5 spans.

"The whole of the materials for the work had to be carried over ten spans of the dam, through which the river had been flowing since January, on a rough temporary bridge, and the progress during the month in crate work, concrete, masonry and pitching amounting to 1,10,122 * cubit feet, made it very difficult to keep the works supplied with materials, as everything, including clay for filling and fuel for engine, had to pass over this bridge.

* Crate work	or	11,000
Concrete		30,122
Masonry		17,000
Pitching		52,000
TOTAL		1,10,122

"Fortunately the work progressed so rapidly that by the end of the month all the masonry with the exception of a few noses of piers was completed, and only the clay filling and some pitching in spans 11 to 15 remained to be done. A high flood was reported from Madhopur on 1st April, and everything was done to hurry on the completion of the dam before the arrival of the flood. On the morning of 5th all the clay filling down stream pitching and crate work were completed, but about 200 feet of the up stream pitching was left undone.

"On the 5th, the river rose to 7·5 feet above the crest wall in the 10 open spans, and as the rush through them was very great, the bunds round the rest of the dam were cut, and the Ravi was allowed to flow over the whole dam.

"There was no damage done by the flood, which rose to 6 feet over the whole crest wall, and the 200 feet of unprotected clay filling on the up stream side of the dam can easily be covered with pitching, by dropping the materials into the water, if it is thought necessary to do so.

"The dam is therefore practically complete with the exception of needles, which are now being manufactured."

Work retarded by illness of Executive Engineer and Sub-Divisional officer.

35. It may here be mentioned that during March and beginning of April work was carried on day and night, and that both the Executive Engineer and the Head Works Sub-Divisional Officer were at the end of March laid up with fever caused by constant exposure in the trench: the latter officer had to carry on work through his subordinates, otherwise all the pitching would have been done before work was stopped for the season by this flood.

Additional points to be noted.

36. Besides the difficulties in construction of the foundations of the dam due to the novel nature of the design, and to the unprecedented floods which came down the river in January, February, March and April 1885, there is nothing of particular importance to be noted, except that considerable loss and delay were caused by the engine and pump breaking down at critical times, when in a few hours the water would rise over the work. It may also be mentioned that all the concrete was faced with brick work in alternate layers of headers and stretchers.

Experiments with needles.

37. Ever since the dam was practically completed in April 1885, there has been a continual series of experiments to find out the best way of working the needles and making the dam as safe and efficient as possible, and now, in 1888, there seems nothing to be desired except the power of removing the needles from their position in the dam, during floods by some simple mechanism, for, in spite of precautions, a flood has on two occasions worked from the shore, arrived unexpectedly, and caused the needles to jam, so that they could not be removed.

Fixing beams to piers.

38. One of the first things brought to notice in 1885 was the advisability of fixing the beams to the piers, so as not to float off during floods, as it was found that they would knock themselves and the piers to pieces if allowed to float off according to the original idea, whereas by remaining fixed to the piers they caused no inconvenience.

Shearing off of the top of a pier.

39. In 1885, when there was a head of about 6·5 feet water against the dam, the top of one of the piers near the centre of the dam suddenly sheared off, thus opening two bays, and had it not been for the prompt action of the officer in charge, who opened the whole dam in about half an hour, considerable damage to the Down stream pitching must have occurred, but except a deep hole in the sandy bed of the river, nothing resulted from this accident.

Cause of failure of pier and iron work designed to prevent such accidents.

40. The pier which thus failed had been damaged by a large boat, and the top had recently been repaired, so that when the accident happened the mortar had not thoroughly set. To prevent the re-occurrence of any such accident, the iron work shown on the drawings of the dam was added, with the double object of holding down the beams and of transmitting the pressure of the water held up from the beam down the pier and along the crest wall

Dimensions of needles.

41. The needles are made of deodar wood, a little in excess of the calculated dimensions, and their weight (36 lbs. dry and 40 lbs. wet) is such that a strong man can just manipulate them. Their dimensions are $7\frac{1}{4}' \times 5'' \times 3\frac{1}{2}''$, with a stout handle $1\frac{1}{4}$ feet long ending in a knob. (See drawing No. VIII.)

Importance of making dam water tight.

42. Of all the problems to be solved that making the dam water tight was most important, as it was clearly of great consequence to the efficiency of the work that no water should be allowed to pass when the supply in the river was less than that required for the Canal, and no trouble was spared to find out the best method of preventing leakage.

Needles, with grooves and pins.

43. The Executive Engineer at first proposed the following method, which would ensure the needles fitting perfectly tight (see Drawing No. IX).

The needles AA have a cross pin 3 inches from the bottom end, projecting on each about $\frac{3}{4}$ inch; BB are needles with a slot $\frac{1}{2}$ inch wide and 1 inch deep, cut down the centre of each side from top to bottom.

When it is required to close a span, grooved needles were to be put in position, up to about three quarters of the total number required to close the span, and the needles with pins A A then forced down from the top, each between two grooved needles, the pin sliding down in the grooves, and forcing the adjacent needles to the true distance apart.

Grooved needles unnecessary and method adopted for making dam water tight.

44. This device was, however, found to be unnecessary, as experience showed that if ordinary needles are fixed sufficiently close together, and if the interstices between them are filled up with wood shavings, chopped up straw, or any other such rubbish, the whole dam can be made quite water-tight. The method now adopted is as follows :—

After the needles have been placed in position they are forced close together by a man standing on the pitching below the dam, who inserts a crowbar with a wedged-shaped end into the spaces between them, and forces the needles along the face of the crest wall.

A basket fixed to a bamboo, about 10 feet long and filled with the closing materials, is then slipped down in front of the leak to be closed, when the light material is sucked into the opening by the current, and, sticking there, closes the opening.

Waterproof cloth shutter for stopping leaks.

45. It very often happens that when putting the needles into position, as described above, they do not fit closely, and when there is a great difference of level between the water surface above and below the dam, the rush of water through the interstices make it very difficult for a man to stand on the pitching below and use his crowbar; but this difficulty is overcome by letting down a shutter of oiled canvas or tarpaulin, in front of the part where there is excessive leakage; the flow of water is then at once stopped.

Method of working shutter.

46. The method of working this shutter is as follows :—

A piece of tarpaulin, or oiled canvas, 8 feet long and 6 feet broad, is fastened at one edge to a wooden bar, $6\frac{1}{2}$ feet long, with handles at each extremity, and at the opposite edge to a bar of round iron, 6′-4″ long and one inch diameter; it is then rolled up on the iron bar and the roll thus made is placed in front of the needles, where excessive leakage exists, with the wooden bar in a horizontal position above the water surface. Its ends are then tied, or held in position, by the handles at each end, so that when the rool is let go it unfolds itself and the weight of the iron bar causing it to roll down the face of the needles under water, it at once closes all leakage in the area covered, being pressed tightly against the needles by the water.

At each end of the iron bar round which the shutter is rolled a loose collar is fastened and cords tied to the collars, so that when the bar sinks in the water and enrolls the shutter, one end of each cord is carried down, the other end remaining in the hand of the operator, and when it is necessary to take up the shutter it is pulled up from the bottom by these cords.

Water-proof shutter only newly tried but promises to be exceedingly useful.

47. This shutter has only lately (March 1888) been tried, and it promises to be exceedingly useful in reducing to a minimum the labor of making the needles water-tight, especially in the needle lock, where the needles have to be put in afresh each time that a boat passes through.

Placing needles in position.

48. The method of placing the needles in position in the first instance is shown in drawing No. X, and in no case has the shock of a needle closing on the crest wall broken the needle when the wood was sound.

Regulating by pushing forward.

49. In order to regulate the height of water above the dam, there is ordinarily no necessity for removing needles, as the object can be obtained by pushing forward a sufficient number of needles, as shown on Drawing No. XI, so that water can rush through the open spaces.

Opening needles by extracting lever.

50. When it is required to allow more water to pass the dam than can escape by means of pushing the needles forward, it is necessary to remove as may be found sufficient, and this can generally be done without any mechanical contrivance, but when the needles have "jammed" from any cause, or the pressure against them is too great, they can be at once removed by a lever designed by the Executive Engineer, which is shown in the Drawing No. XI.

Frame for opening needles.

51. In case of the force required to open needles for regulating purposes as described in paragraph 50 being found too great for unaided manual labour, a frame working with blocks and tackle, which is powerful enough to open them in all cases, has been designed by the Executive Engineer (see Drawing No. XII).

Difficulty and danger of working dam from beams without a foot bridge.

52. The difficulty of working the needles with safety from the beams (which are only 18 inches wide) was always a serious one, and in extracting needles with the lever, there was danger of the operator falling into the river if the needles came up suddenly; on one occasion a khalassie fell off the dam, and was drowned, and last August, when making experiments with needles during a high flood, the Executive Engineer also fell off the dam and narrowly escaped drowning.

Foot bridge added.

53. A foot bridge, for the men to work from, was therefore added to the dam, and it has already been found most useful and convenient.

Design of foot bridge.

54. The foot bridge consists of two flat bottomed 60lb rails, 3 feet apart with 3 inch planking between them, the rails being kept together by tie bars, and fastened down to the piers at each end by 1 inch iron rods, imbedded in the masonry, one of the rails being close up to the beam of the dam.

Planking of foot bridge perforated.

55. In order to lessen the shock to the bridge from waves from below during floods, when the whole dam is submerged, the planking is perforated with a large number of 1 inch auger holes.

Trollies for removing needles.

56. In order to remove the needles rapidly and economically from the dam, it is proposed to have two small trollies running on the rails of the foot bridge, one working from each end. Supposing that the trolly only carries the needles for half a span, *i.e.* 24 at a trip, half the needles in the dam would be removed by one trolly in 32 double trips of an average distance of $\frac{733}{2}$, or 366 feet (*i.e.*, half the length of the dam) the total distance being $366 \times 32 = 11{,}712$ feet; this has not yet been tried, but the necessary arrangements are being made.

Establishment for working the dam.

57. The establishment required for the ordinary working of the Dam and Canal Regulator are—

	R
1 Mate @ R12, a month	12
6 Beldars „ „ 7-8, „	45
Total per month	57

When extra men are required for unusual work, they are put on as daily laborers.

Intimation of the approach of floods.

58. Arrangements have been made to have telegrams sent to the Executive Engineer, Lower Sutlej and Chenab Division, Multan, and to the Officer in charge of the Head Works, *vid* Kacha Khu Railway, station of the North-Western Railway, intimating any rise of one foot or more in the Ravi during 24 hours at Madhopur and Shahdera (Lahore) respectively, as floods take a minimum 5 days from the former and 2 days from the latter place to reach Sidhnai, these telegrams have been found most useful both in securing the safety of the dam, and in giving timely notice of the approach of water and of the consequent necessity for regulation.

Rules for working dam.

59. The Rules for working the dam sanctioned by the Chief Engineer, in 1887, are given below—

Rules for working Sidhnai Dam.

I.—The required level of water above dam is to be maintained by opening and removing the needles at a height to be fixed from time to time by Executive

Engineer. The usual height to which water will be kept above dam is 6·5 feet above crest wall of dam, *i.e.* one foot below top of beams, giving a supply of 5·5 feet water of canal.

II.—Anything above 12·5 feet at Bukrola, or 9 feet at Shahdera, is to be considered a flood.

III.—On a flood being telegraphed, the needles are to be removed one day before it can arrive, so as to reduce the depth of water above the dam to 6 inches above the full supply required in Canal at the time.

IV.—As the river begins to rise on the approach of the flood, the needles are to be removed gradually.

V.—As soon as the river begins to fall, the needles are to be replaced, so as to raise the water again to 6·5, if there is no intimation of another flood coming. Should there be any such intimation, sufficient needles only need be put in to raise the water to a height of 6 inches above the supply required in the Canal at the time.

VI.—As a matter of routine, when the surface of river below the dam is at the height fixed in Rule I, all the needles are to be removed.

VII.—In special cases, for purpose of training the river and removing silt deposits from in front of the Canal Regulator and below the lock, it may be necessary to put in needles when the level of water below the dam is more than that fixed by Rule I, but in all cases written instructions on the subject must be obtained from the Executive Engineer by the Head Works Sub-Divisional Officer.

VIII.—As accumulations of floating rubbish are constantly forming against the needles when the river is high, great care must be taken to have them regularly removed by the Dam Beldars, and the Head Works Sub-Divisional Officer shall, during the flood season, inspect the dam at least once a day, and see that this is done.

IX.—In order to prevent silt deposits in front of the Canal Regulator and above and below the lock, the needles should always be distributed in the dam, so as to force a strong current on to these places when there is any sign of silt being deposited.

Soundings are to be taken along lines previously marked out, and recorded every three days to show the state of the river at these places with reference to this Rule, and any serious accumulations are to be reported at once with a chart of soundings to the Executive Engineer, with a view to obtaining the written instructions mentioned in Rule VII.

X.—Soundings are to be taken and recorded weekly, and on the subsidence of each flood, showing the state of the river bed along the line of crates at the toe of the pitching below the dam, and any serious scour is to be at once reported to Executive Engineer. Pitching blocks should be thrown into the hole scoured out if the depth goes on increasing.

XI.—The Head Works Sub-Divisional Officer will be responsible for maintaining the supply in the Canal in accordance with the requirements of the Officer in charge of the Sidhnai Canal Sub-Division, which will be communicated to him in writing from time to time. He shall not raise the supply in the Canal except on the written order of the said Sub-Divisional Officer or of the Executive Engineer, but he may at his discretion lower the supply on the receipt of a report, written or verbal, from any canal servant of an accident having occurred to the Canal, or if the state of the Head Works requires him to do so. In such cases, however, he is at once to report his reason for lowering the supply to the Executive Engineer and to the Officer in charge of the Sidhnai Canal Sub-Division.

Additional pitching, 1886.

60. During the flood of season 1886 a hole formed below the dam in the sandy bed of the river, and the few of the crates and some of the pitching were disturbed, but no damage of any consequence happened. In order to guard against the danger of this hole forming again and damaging the work, a 10 feet length of additional pitching was added, making the length in the sand foundations 50 feet.

Additional pitching, 1887.

61. In the floods of 1887, when the highest flood on record passed down the Ravi, this hole formed again, but further away from the dam than the previous one, and 10 feet more pitching was added, making the length of pitching in the central portion 60 feet; it is now hoped that the dam is safe

from the effects of any flood, if the needles are worked with proper care, and that the only expenditure on maintenance will be in throwing in some pitching blocks every year at the toe of the pitched slope, to make up for the loss by subsidence in the shifting sand of the river bed.

Canal does its own silt clearances.

62. It is found that the pool formed above the dam acts as a settling basin in which much of the silt held in suspension by the water is precipitated, the result being that during most of the year the water entering the Canal is so free from silt that any silt which has been deposited in the bed during the flood season is picked up and carried on into the Distributaries, and thence on to the land. In this way expensive Canal and Rajbaha silt clearances are avoided, and as far as can be seen at present, the only silt clearance required on the Sidhnai Canal will be an annual one in the first two miles. Last year this only cost ₹2,000.

Silt deposits above dam removed by floods.

63. The silt which is deposited in the river above the dam during times when the river is low, is washed away during the flood season when the dam is open, so that no danger need be feared from any such deposit accumulating.

Cost of the dam, &c.

64. The dam cost ₹99,613, showing a slight saving on the sanctioned estimate.

SIDHNAI CANAL.

Dam at Head.

Report on Beams and Needles.

Dimensions of beams.

The beams for supporting the needles are 18″ × 12″, as shown in the drawing, and are indeed sawn somewhat more, or about 18½ feet × 12½ feet.

Horizontal strength of beams.

2. If water is held up 7½ above the crest wall, then the total distributed horizontal pressure on a beam 20′ span—

$$= \frac{20}{3} \times \frac{(7{\cdot}5)^2}{2} \times 62{\cdot}4$$
$$= 11{,}700 \text{ lb.}$$

and using the formula generally accepted for strength of deodar beams $bd^2 = \frac{WL}{100}$, and taking $b = 12''$—

$$\therefore d^2 = \frac{11{,}700 \times 20}{100 \times 12} = 195$$

and $d = 14''$ nearly.

Vertical strength.

3. The needles being on a slope of 1 in 5 the vertical load on the beam will be $\frac{1}{5}$ × (weight of needles + horizontal pressure of water) + weight of beam.

The weight of each needle 5″ broad = 30 lb, and there are 48 in each span, so that the vertical load on the beam is—

$\times 30 \times 48 = 288$ lb $= \frac{1}{5}$ the weight of the needles
$+ \frac{1}{5} \times 11{,}700 = 2{,}340$ „ $= \frac{1}{5}$ the horizontal pressure
$+ 1{\cdot}5 \times 1 \times 20 \times 40 = 1{,}200$ „ = the weight of the beam
Total . 3,828 lb

and assuming $b = 18''$, then

$bd^2 = 3828$ and $d = \sqrt{\frac{3828}{90}} = 6{\cdot}5$ inches.

Vertical stiffness.

4. Assuming the safe deflection to be $\frac{1}{480}$ of span, the necessary depth for a breadth of—

$$18'' = \sqrt[3]{\frac{L^2 W}{725}} = \sqrt[3]{\frac{400 \times 3{,}828}{72 \times 18}} = 10{\cdot}57''$$

Horizontal stiffness.

5. In this case for a breadth of 12″ necessary depth

$$= \sqrt[3]{\frac{400 \times 11700}{72 \times 12}}$$
$$= 17{\cdot}56''$$

General results.

6. From these figures it is clear that the beams are strong enough to stand any stress they can possibly have to bear from water pressure, and casual blows from floating bodies.

Conditions of a needle.

7. If 7·5′ water is again taken as the depth over the crest, the needles will be subjected to a pressure which is that due to 1′ depth of water at the lower side of beam, and 7·5′ at upper surface of crest wall.

Let l = distance between support of needle = 6·5.
P = pressure at lower surface of beam, due to the water below that point.
w = weight of c.ft. of water

Then $P = \frac{wl^2}{6} \times \frac{wl}{2}$ . . . . . (1)

and bending moment M at any depth x below bottom of beam—

$$= Px - w\left(\frac{x^3}{6} + \frac{x^3}{2}\right) \quad . \quad . \quad (2)$$

to find the position of maximum bending moment differentiate with respect to x and equate to o—

$$\text{Thus, } \frac{dm}{dx} = P - w\left(\frac{x^2}{2} + x\right) = o$$

$$\text{and } x^2 + 2x + 1 = \frac{2P}{w} + 1$$

$$\text{therefore } x = \sqrt{\frac{2P}{w}} + 1 - 1$$

$$\text{(or substituting value of P)} = \sqrt{\frac{P}{3}} + l + 1 - 1 \quad . \quad . \quad (3)$$

Substituting in (3) $l = 6{\cdot}5'$

$$x = 3{\cdot}646 \text{ feet}$$

Again substituting $l = 6{\cdot}5$ in (1)

$$p = 62{\cdot}4\left(\frac{(6{\cdot}5)^3}{6} \times \frac{6{\cdot}5}{2}\right) = 642{\cdot}2.$$

Also substituting in (2)—

$$M = 642{\cdot}2 \times 3{\cdot}646 - 62{\cdot}4\left(\frac{(3{\cdot}646)^3}{6} + \frac{(3{\cdot}646)^3}{2}\right)$$
$$= 2{,}341{\cdot}45 - 918{\cdot}77$$
$$= 1{,}422{\cdot}68 \text{ ft. lb.}$$

Now, the formula $bd^2 = \frac{wl}{100}$ is for beams with a uniformly distributed load for which—

$$M = \frac{wl}{8}$$

and putting M into terms of b and d—

$$M = 12{\cdot}5\ bd^2,$$

$$\text{Taking } b = 12'', \ d = \sqrt{\frac{1422{\cdot}68}{12 \times 12{\cdot}5}}$$
$$= \sqrt{9{\cdot}481},$$
$$= 3{\cdot}07 \text{ inches.}$$

8. If the maximum working stress on the most strained fibres of needle is taken at 1,000lb per square inch, the dimensions may be calculated as follows (see Rankine's Civil Engineering, page 162) :—

Maximum thickness of needles.

$\frac{f}{y}\ i = 1{,}422{\cdot}68$ ft. lb $= 17072{\cdot}16$ inch lb.

$f = 1{,}000$; $y = \frac{d}{2}$; $i = \frac{bd^3}{12}$;

therefore $\frac{1{,}000\ bd^2}{6} = 1{,}7072$ lb.

and if $b = 12$, $d^2 = 2{\cdot}92$, and $d^2 = 8{\cdot}536$.

From this it would seem that 3″ thick would be the proper dimension at the point of maximum bending action, and it is also pointed out that the point of maximum bending action does not correspond with centre of pressure which divides the needle into segments in the proportion of 2 to 1.

Chapter III.

Needle Lock.

1. On the occasion of Chief Engineer's visit to Sidhnai in February 1885, it was brought to his notice that when water was headed up by the dam to any great extent, it would be impossible to pass boats up or down the river without lowering the water above the dam, and wasting a large amount of water, besides possibly lowering the supply in the Canal.

Necessity for lock.

2. During the hot season of 1885 a register of traffic up and down the Ravi was carefully kept, and the result was that the Chief Engineer sanctioned the preparation of a design and estimate for a lock.

Register of traffic.

3. The Executive Engineer submitted several designs for a lock, worked with needles, instead of ordinary gates. The question was then raised whether the beams supporting the needles should swing round in a horizontal plane or be raised in a vertical one when opening the lock, and ultimately the latter method was adopted.

Preparation of designs.

4. The final design and estimate for the lock were sanctioned in the end of October 1886, and early in November, as soon as the Ravi has fallen sufficiently to admit of work being started, the site of the work

Final design sanctioned and commencement of work.

was surrounded by an embankment enclosing three spans of the dam, and allowing room for depositing materials inside the embankment.

5. The whole of the lock foundations are in hard clay, and consequently no pumping by steam was required to unwater the foundations.

Foundations and pumping.

6. There was no trouble in laying the concrete foundations, which were made according to the sanctioned specification and design, and the same may be said of the masonry.

Concrete and masonry.

7. Clay filling below the pitching was done with the clay excavated from the foundations, well rammed, and there has been little or no subsidence.

Clay filling.

8. The pitching is of the same description as that of the dam.

Pitching.

9. The upper beam is 1½ feet × 1′ in cross section, the same as the beams of the dam, and the lower beam having to support 1½′ more depth of water is made 1½′ × 1½′.

Dimensions of beams.

10. The hinges of the beams are fixed to bolts strongly built into the masonry, the one of the upper beams being in a horizontal position in the wall, and the one of the lower beam in a vertical position, because the side wall at that place is too thin to admit of the bolt being fixed horizontally.

Hinges.

11. The side stays which keep the beams in position laterally, keep the hinges safe from all torsion, and the greatest strain they are subjected to is the whole weight of the beam, when it has been raised to a vertical position.

Side stays.

12. The needles of the upper bay are the same as those of the dam, *viz.* 10′ × 5″ × 3½″, but those of the lower bay are 11·5′ × 5″ × 4½″ at 4·5′ from the lower side of beam, the point of maximum bending action. The fittings are the same as for the dam needles.

Needles.

13. The arrangement for lifting the beams, as shown in the drawing, is very simple and works perfectly.

Lifting gear for beam.

The crab winch is placed between the rail tripod and sufficiently weighted to prevent the tension of the chain lifting it, and an iron rod has been attached to the front rails of each tripod, by means of which the beams are safely fastened, when they are lifted to a vertical position, so that they cannot fall or lower suddenly in consequence of carelessness on the part of men working the crab winch.

14. The strains on the different parts are shown in the following diagram for lower beam—

Strains on different parts of gear for lifting beams.

W = weight of beam.
Z B H W
$= 23 \times 1{\cdot}5 \times 1{\cdot}5 \times 40$
= 2,070 lbs.

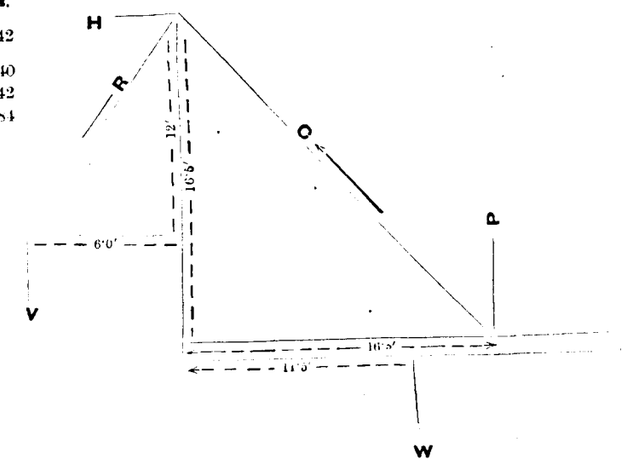
lbs.

$P = \frac{2{,}070 \times 11{\cdot}5}{16{\cdot}5} = 1{,}442$

C = 1,442 × √2 = 2,040

H = P = 1,442

V = 2 H = 2,884



The rail should therefore be weighted with about 3,000 lb of stone, *i. e.* 40 cubic feet closely packed.

15. The pull required to lift the beam is 2,040 lb., and by using blocks to multiply the force three times, the tension on one chain amounts to $\frac{2040}{3}$ = 680 lb and for this a $\frac{3}{8}$" chain has been used, although the strength is largely in excess of the working strain for chains of this size, which is given in Molesworth's Pocket Book as 1 ton, but on one occasion a smaller chain about $\frac{1}{4}$" diameter of iron broke, and it is thought best to have absolute safety with such machinery.

Strains on different parts of gear for lifting beams.

16. The routine of passing a boat through the lock is as follows, supposing that the boat is going down :—

Passing boat through lock.

I. The upper needles are opened, and water admitted into the lock chamber.

II. The needles are then removed, the beam lifted, the boat taken into the lock, and the upper beam lowered.

III. The lower needles are then slightly opened, so as to cause a current to flow through the lock, and the upper needles are then put in ; the current is required to press the upper needles against the upper beam, otherwise they would float.

IV. As soon as the upper needles are in position and fitted close to one another, the lower needles are opened, and the lock emptied.

V. The lower needles are then removed, the beam lifted, and the boat passed out of the lock.

VI. The operations are reversed for a boat going up.

Chapter IV.

General remarks.

In the foregoing description of the works at head of Sidhnai Canal only points which are thought to be of general interest have been touched on ; there is however much information not given in writing which can best be gathered from a study of the drawings of the completed works ; thus, a detailed description of the iron fittings of a needle has not been given, but they are shown clearly in the drawings.

Information of general interest only given in reports.

A specification for each work has not been given, as the specifications of all are similar, and the following may be taken as applicable to all :—

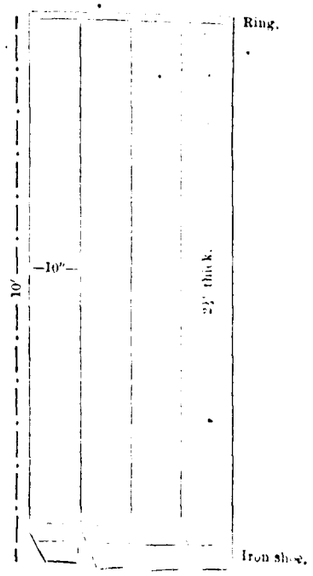
Specification.

I. The excavation of foundations will be executed according to the levels and dimensions shown on the drawings, and on no account is earth to be filled in in the case of the excavation being accidentally made too deep.

Excavation of foundations.

II. Piles in the dam foundations will be of deodar broad-gauge sleepers, 10′ × 10″ × 5″, sawn in two, and will be made as in sketch ; they are to be driven touching each other till the heads are at reduced level 440·0, and in order to ensure accuracy in position the lower end will be shod with iron, and cut in the shape shown in sketch, the head being kept in position by horizontal guides resting on the ground. A moveable iron ring is to be placed on the head of each pile when it is being driven to protect it from being split by the blows of the ram.

Piles.



III. Concrete will consist of 4 parts brick ballast broken to $\frac{3}{4}$ inch size, thoroughly mixed with 1 part kunkur lime "neat," and rammed in 3 inch layers with iron rammers. The brick ballast is to be well soaked in water before being used, and only enough water is to be added in mixing to make the material thoroughly damp ; on no account should enough water be added to make it into shesh. In every case a layer of dry ballast is to be laid on the foundations, before putting on concrete.

Concrete.

IV. Masonry is to be of thoroughly burnt bricks, laid in kunkur lime "neat," and although the joints should be as fine as possible, still they must not be made so fine as to cause danger of any spaces in the joints being left without mortar.

Masonry.

Great care must be taken that the bricks are thoroughly soaked before using, and the practice of using bricks which have only been dipped into water is to be avoided.

Also no mortar made one day is to be kept for use on the next.

V. In laying pitching all the layers must break joint as much as possible, both vertically and horizontally.

Pitching.

VI. The crate work at the slope of dam will be constructed as follows :—

Crates.

The frames are to be made "*in situ*," and the materials consisting of Chiniot stone and brick blocks should be closely packed, the top surface being carefully smoothed over, diagonal wooden battens are to be spiked to the crate frames, so that there can be no chance of any of the materials being washed out.

VII. Woodwork is to be of first class deodar, free from flows and knots, and the beams for the dam must be most carefully selected, as the success of the work depends on their being able to bear the stresses to which they will be subjected.

Woodwork.

VIII. Clay filling will be made in 6 inch layers and will be thoroughly consolidated by ramming, watering, and breaking clods.

Clay filling.

IX. The pitching of the dam is to be gronted and pointed on the upper surface with concrete, consisting of 4 parts pea kunkur and 1 part kunkur lime.

Gronting and pointing pitching.

X. Great care is to be taken that the pointing of the brickwork is done before the mortar gets hard, or the pointing will not adhere properly to the masonry.

Pointing brickwork.

XI. The iron work of the dam is to be fixed to the masonry by chiselling out the holes for the holding down bolts, and after putting them in, filling up the interstices with concrete, made of 3 parts pea kunkur and 1 part kunkur lime, thoroughly rammed and kept damp till it hardens.

Fixing iron work in masonry.

XII. All wood and iron work is to be either tarred or painted.

Painting and tarring.

L. F. MACLINE,
Executive Engineer.

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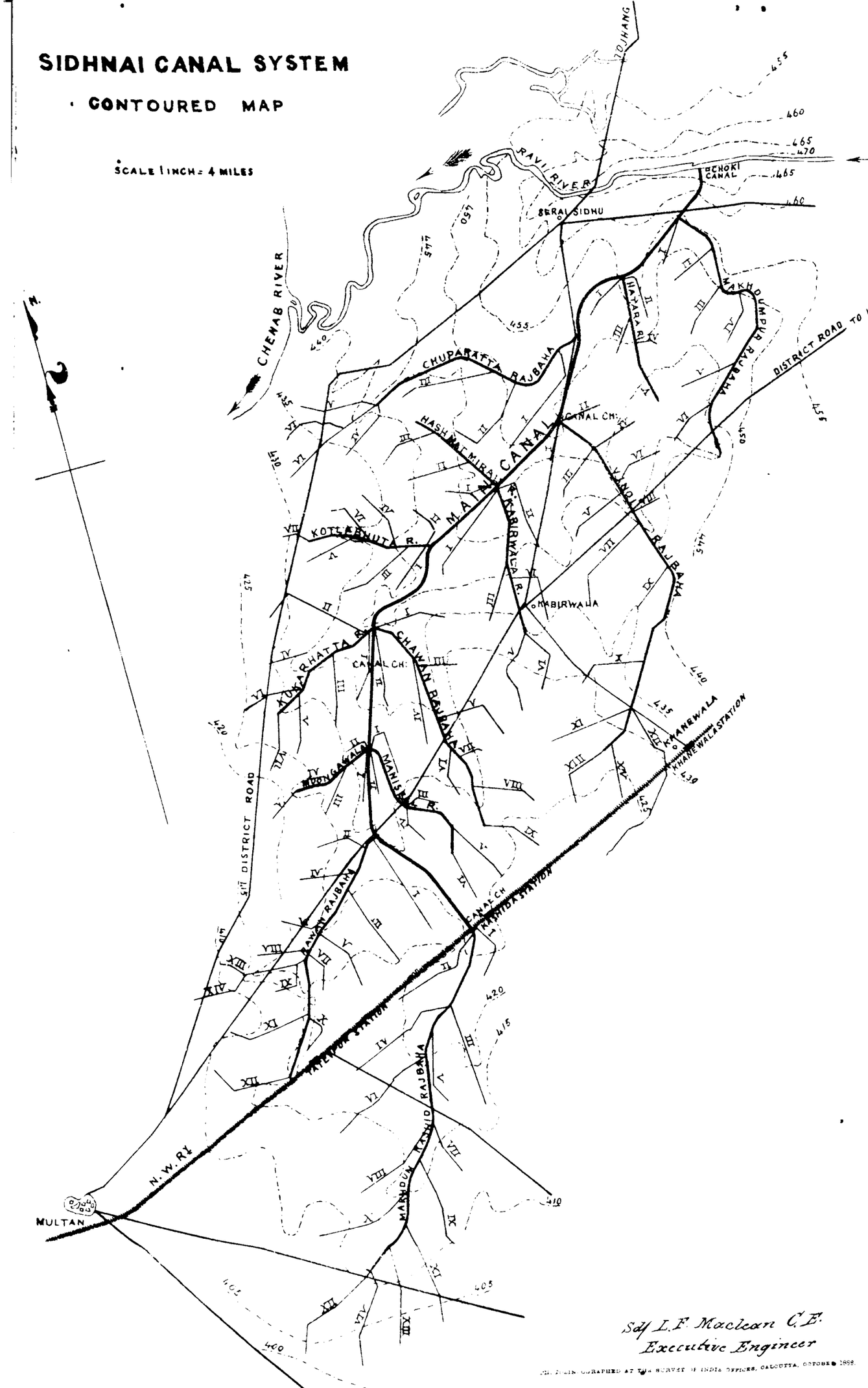
SIDHNAI CANAL SYSTEM

CONTOURED MAP

SCALE 1 INCH = 4 MILES



Sdy L.F. Maclean C.E.
Executive Engineer

LITHOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, OCTOBER 1888.

No I

SIDHNAI CANAL

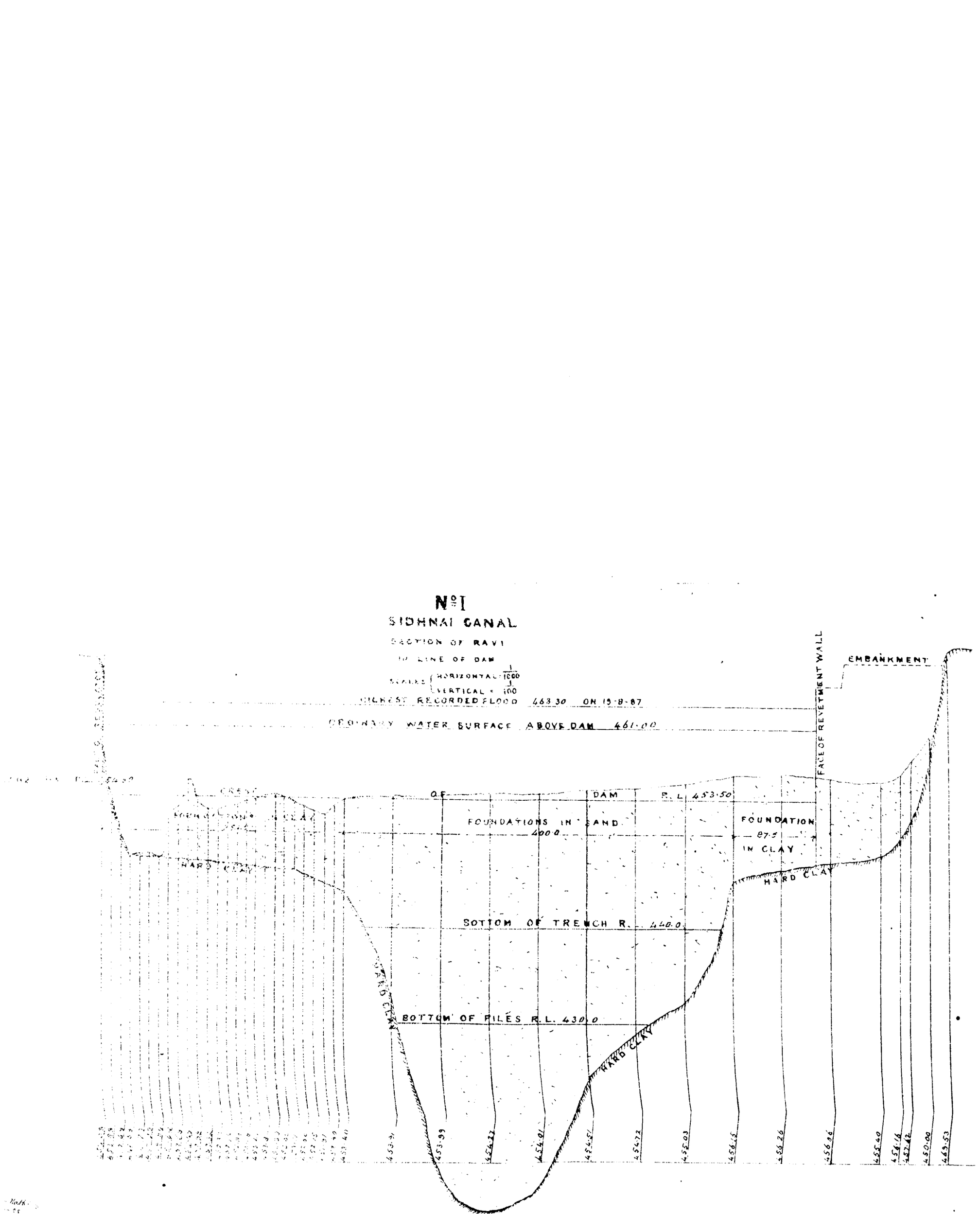
SECTION OF RAVI

@ LINE OF DAM

SCALES { HORIZONTAL = 1/1000 ; VERTICAL = 1/100

HIGHEST RECORDED FLOOD 463.30 ON 19-8-87

ORDINARY WATER SURFACE ABOVE DAM 461.00

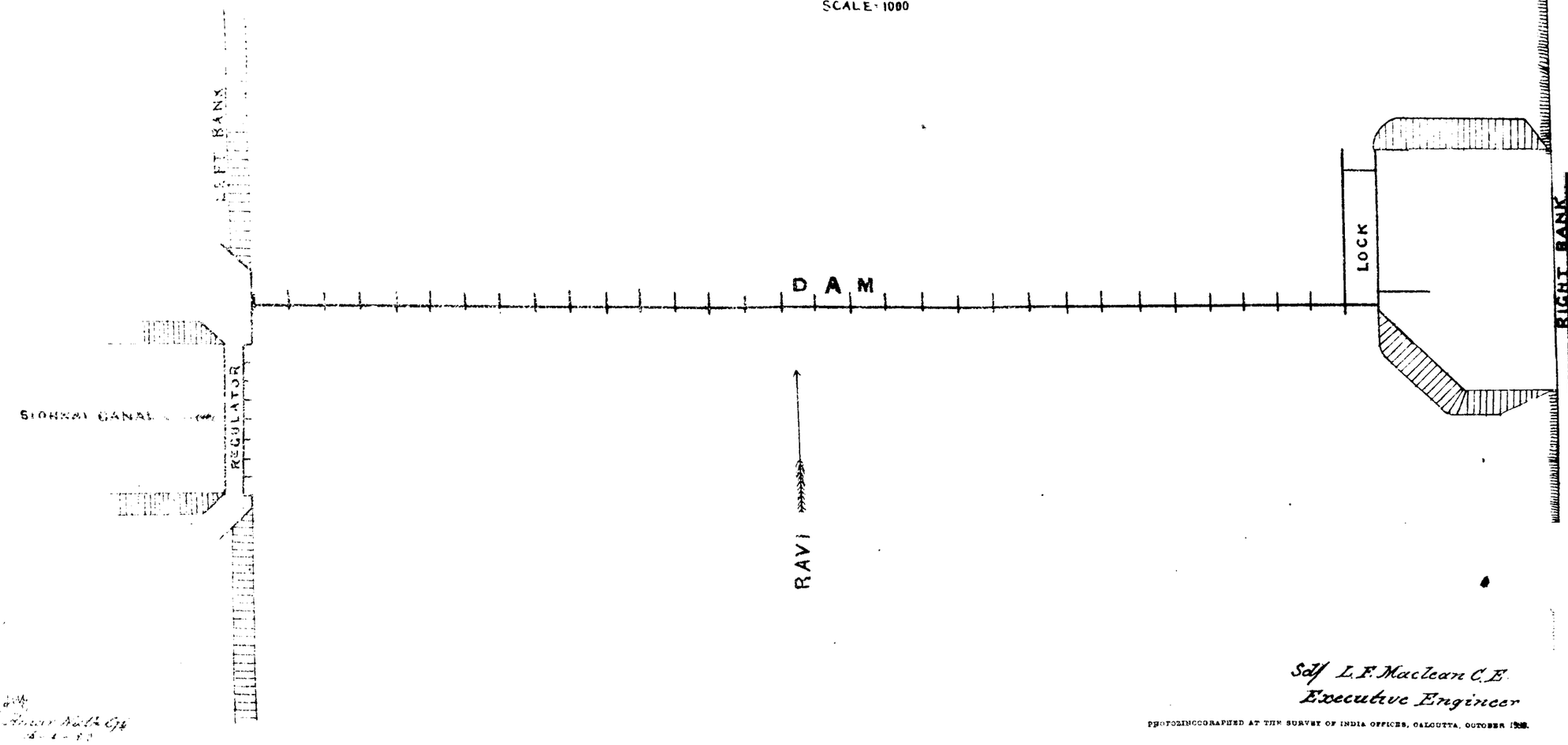


Nº I.A.

SIDHNAI CANAL

HEAD REGULATOR NEEDLE DAM AND LOCK

SCALE: $\frac{1}{1000}$



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Executive Engineer

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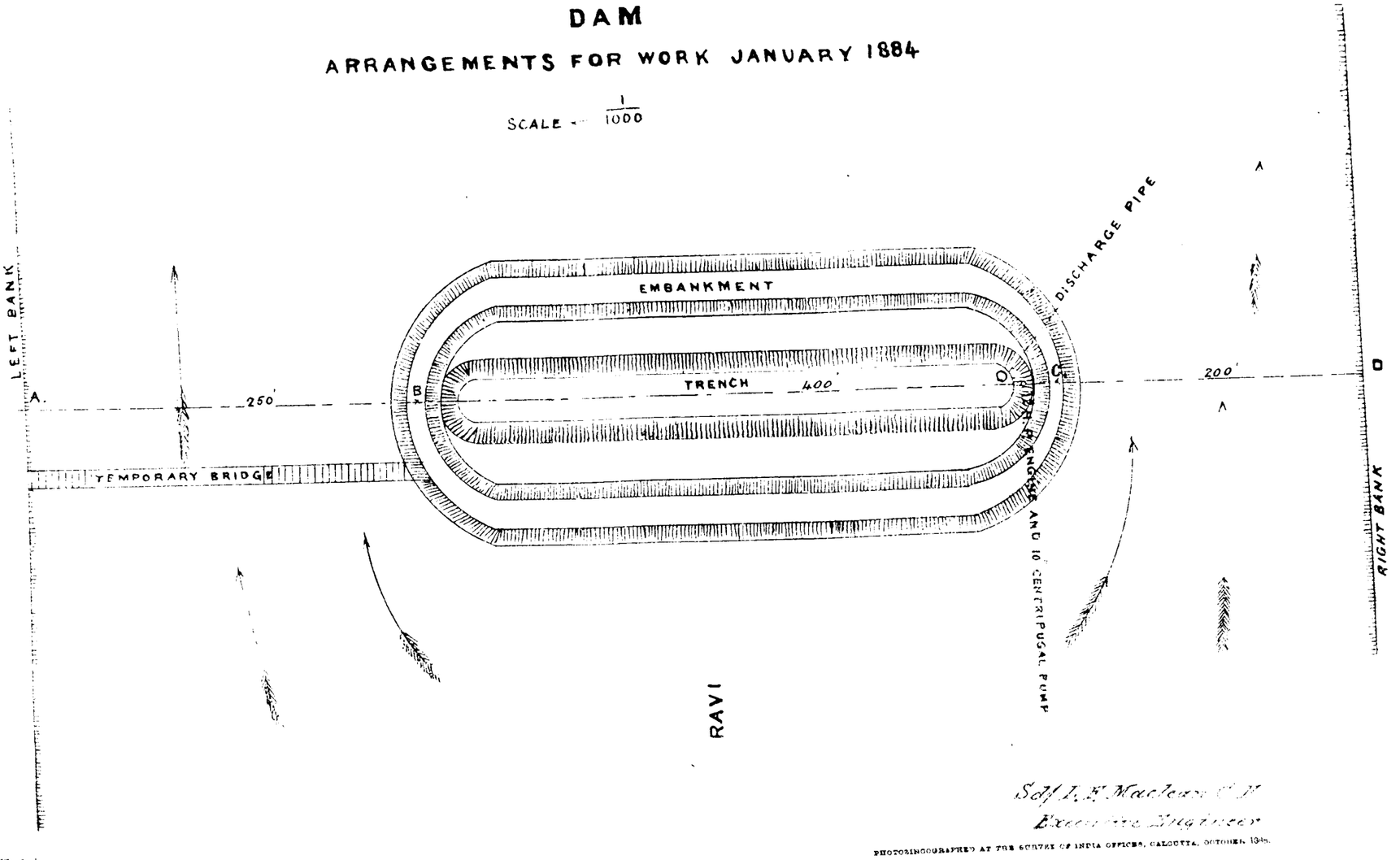
Nº II

SIDHNAI CANAL

DAM

ARRANGEMENTS FOR WORK JANUARY 1884

SCALE — 1/1000



Sdf J. E. Macleane C.E
Executive Engineer

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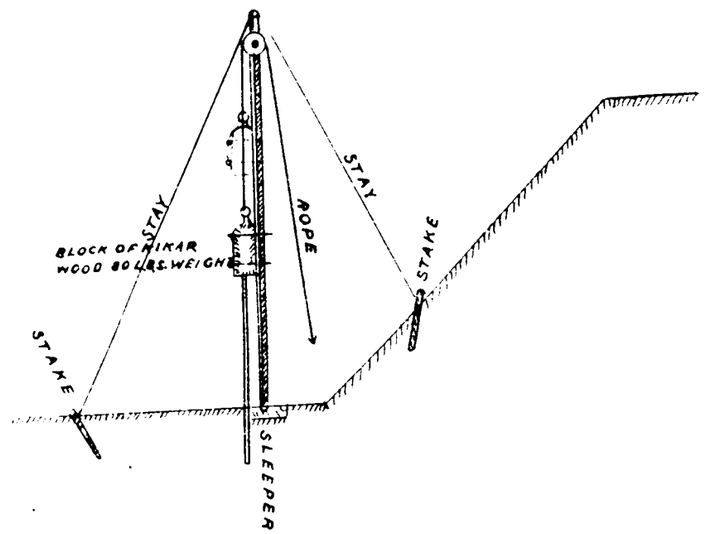
Sd/ Amar Nath C/E
24-6-88

Nº III

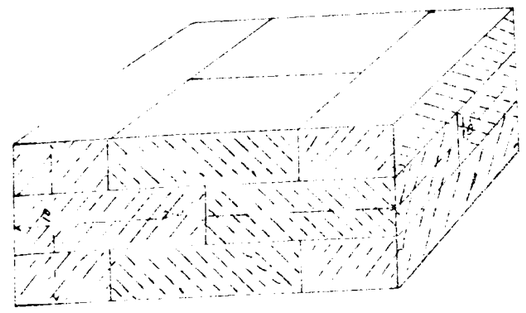
SKETCH OF RINGING ENGINE

SCALE = 1/100



Nº IV

SKETCH OF PITCHING BLOCK



Sdf L. F. Maclean C.E.
Executive Engineer

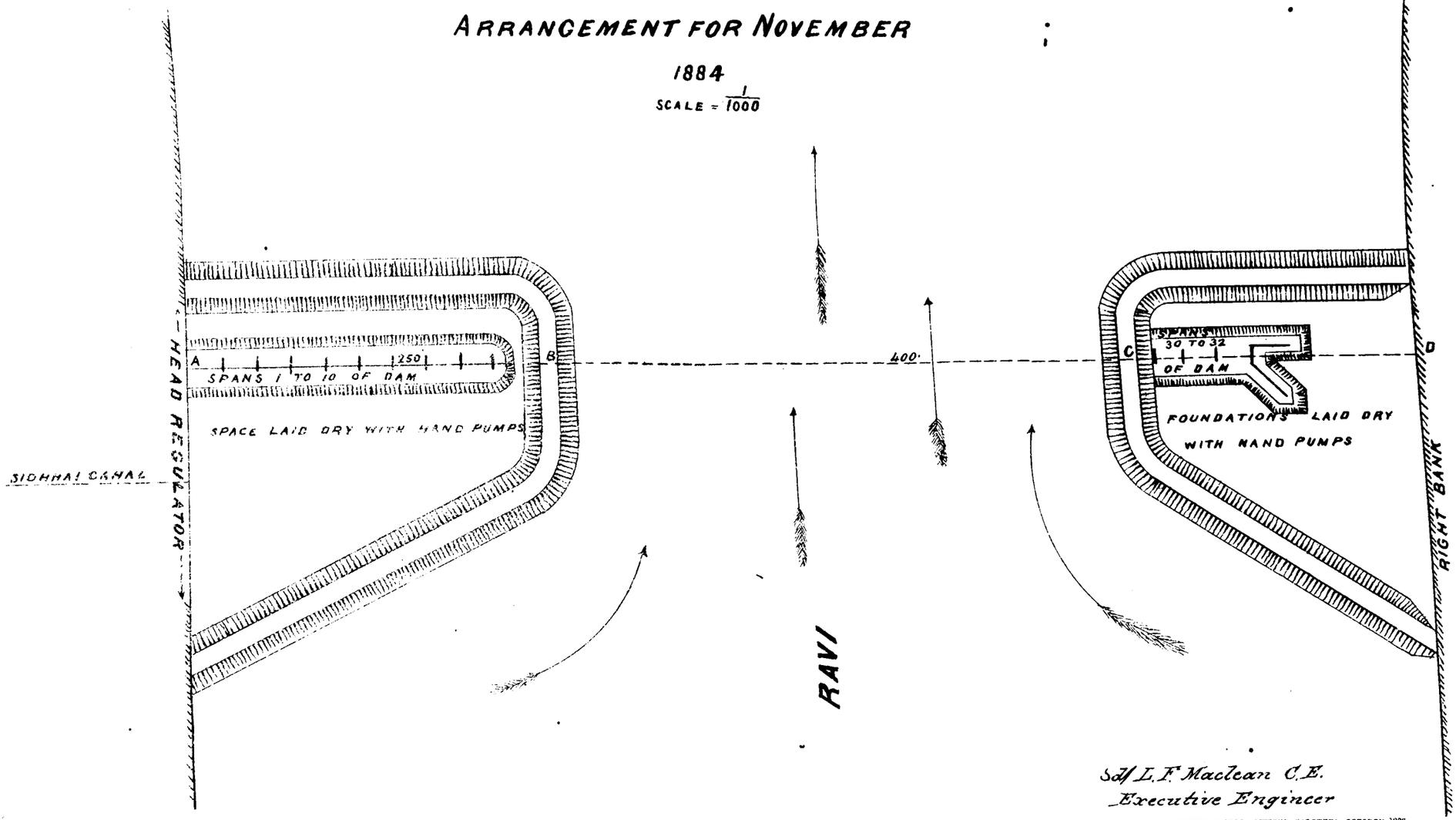
No V

SIDHNAI CANAL HEAD WORKS

ARRANGEMENT FOR NOVEMBER

1884

SCALE = $\frac{1}{1000}$



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Executive Engineer

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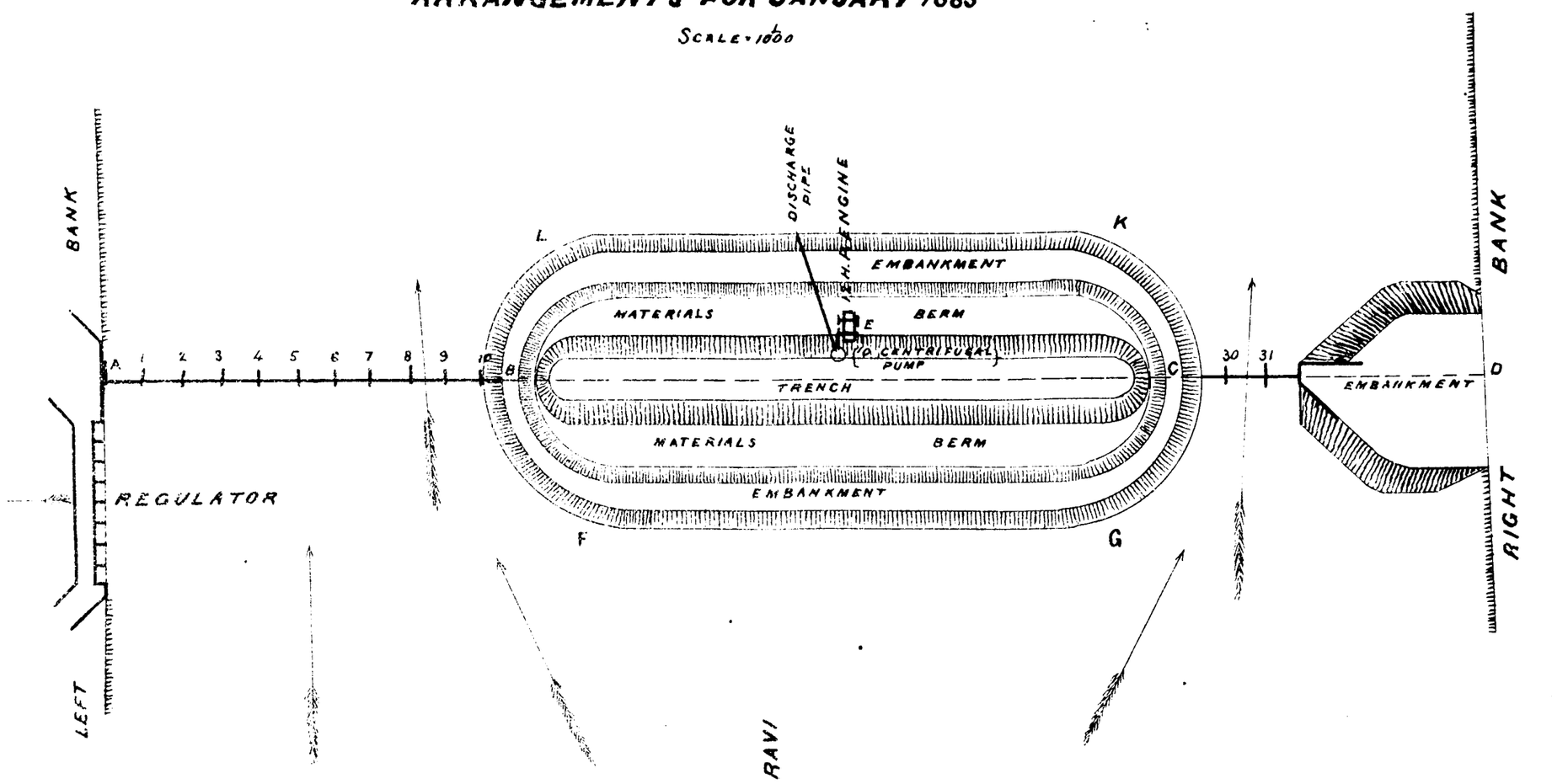
Amar Nath Cpl
26-6-89

Nº VI

SIDHNAI CANAL HEAD WORKS

ARRANGEMENTS FOR JANUARY 1885

SCALE - 1000



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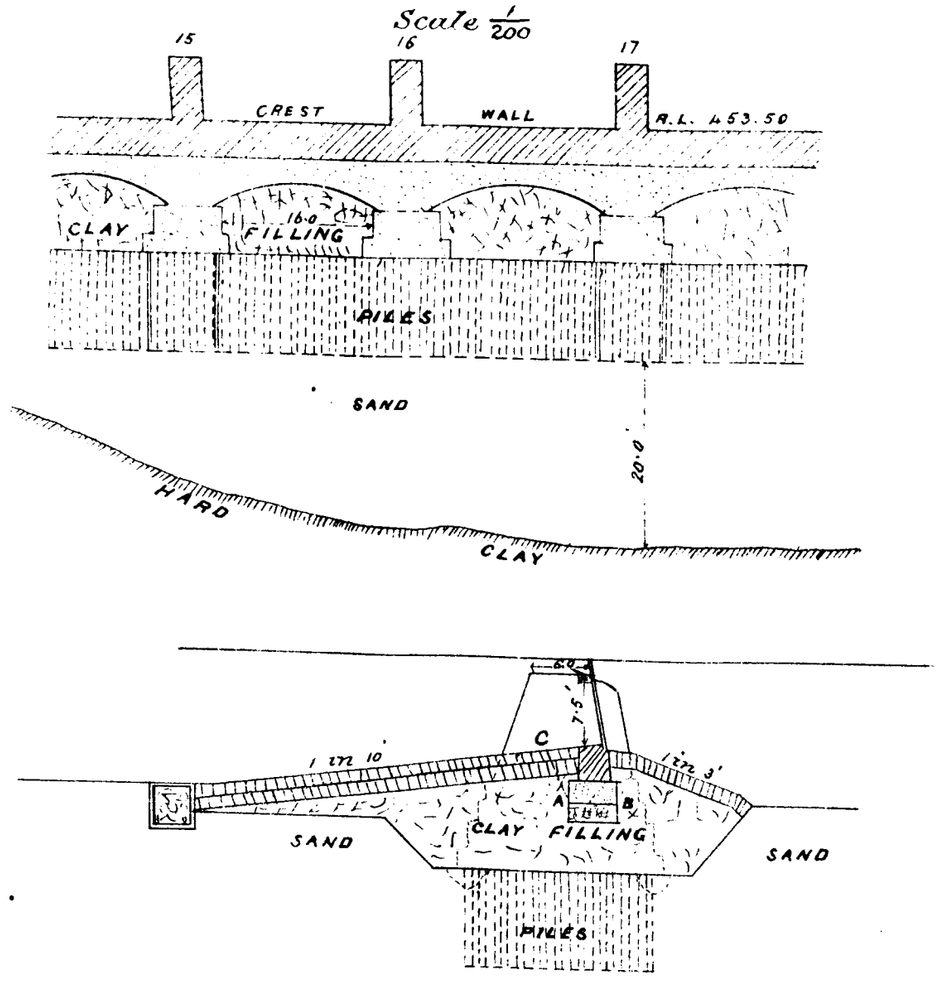
No. VII

Scale 1/200



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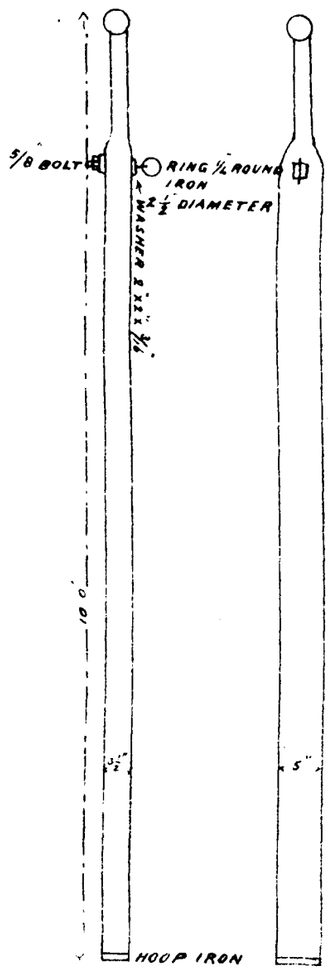
No VIII



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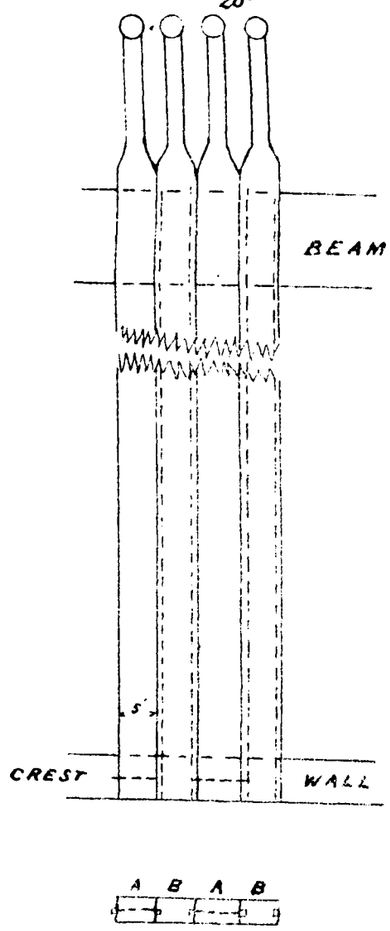
Scale 1/20.



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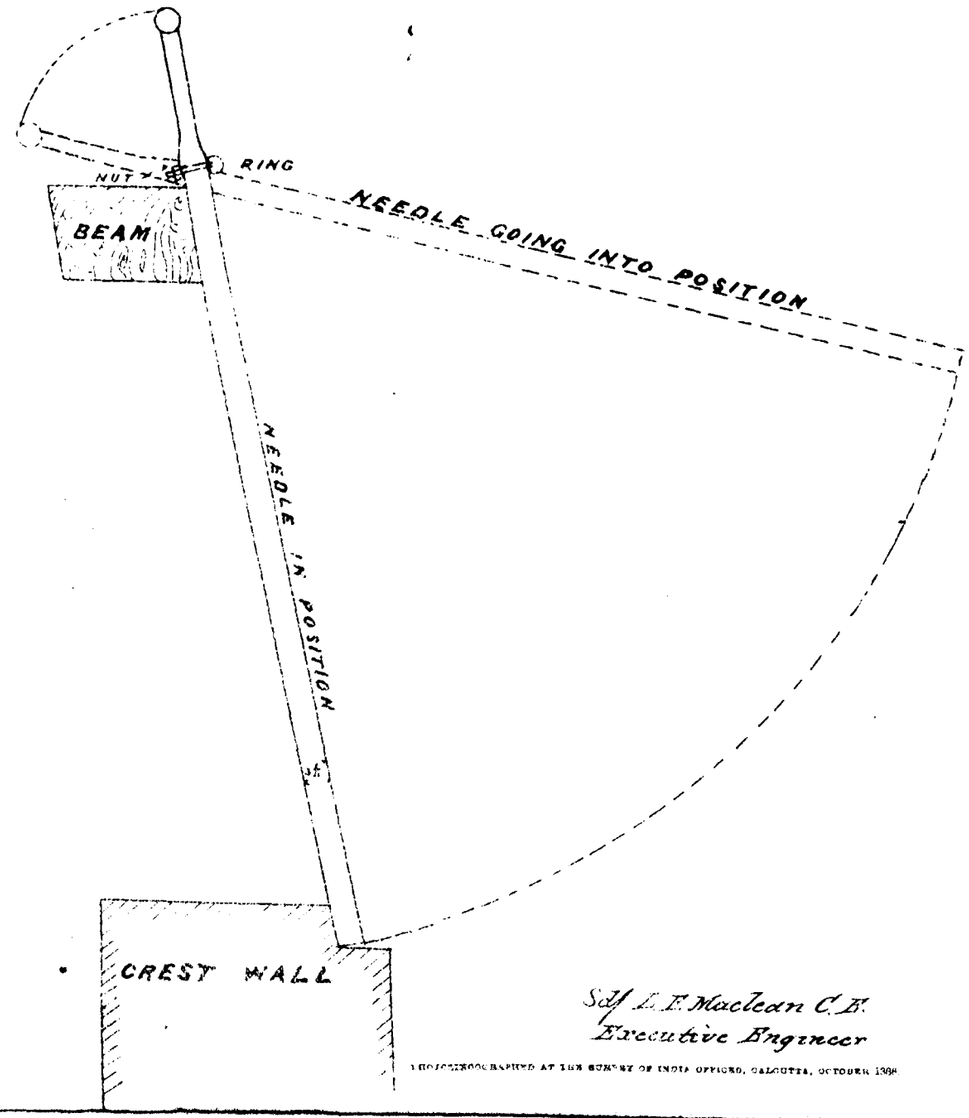

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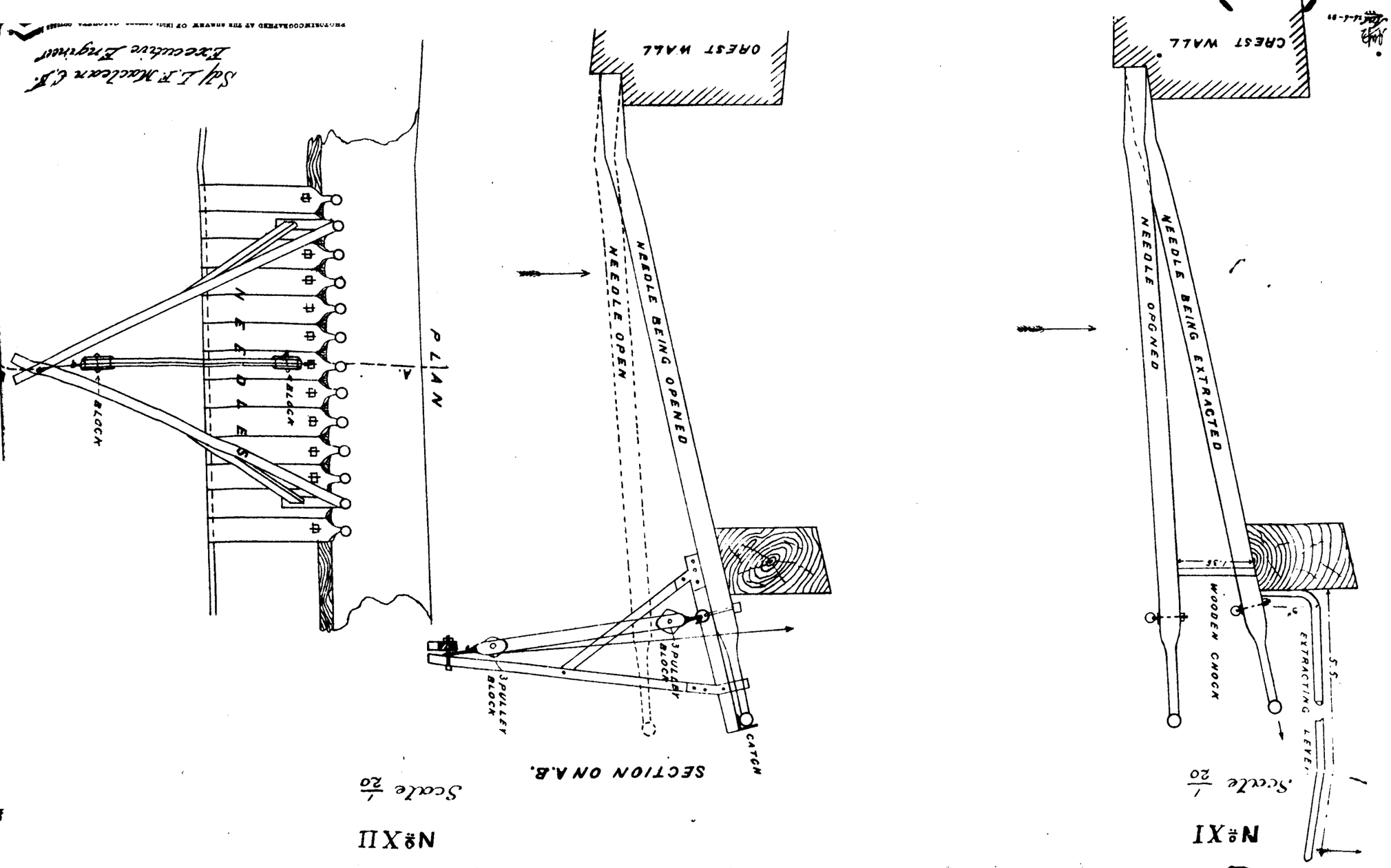
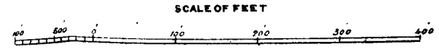

CREST WALL
NEEDLE BEING EXTRACTED
NEEDLE OPENED
WOODEN CHOCK
1.56
EXTRACTING LEVER
5.5
3
Scale 1/20
N° XI
FOREST WALL
NEEDLE BEING OPENED
NEEDLE OPEN
3 PULLEY BLOCK
3 PULLEY BLOCK
CATCH
SECTION ON A.B.
Scale 1/20
N° XII
NEEDLES
BLOCK
BLOCK
PLAN
Sd/ J. F. Macleare C.E.
Executive Engineer

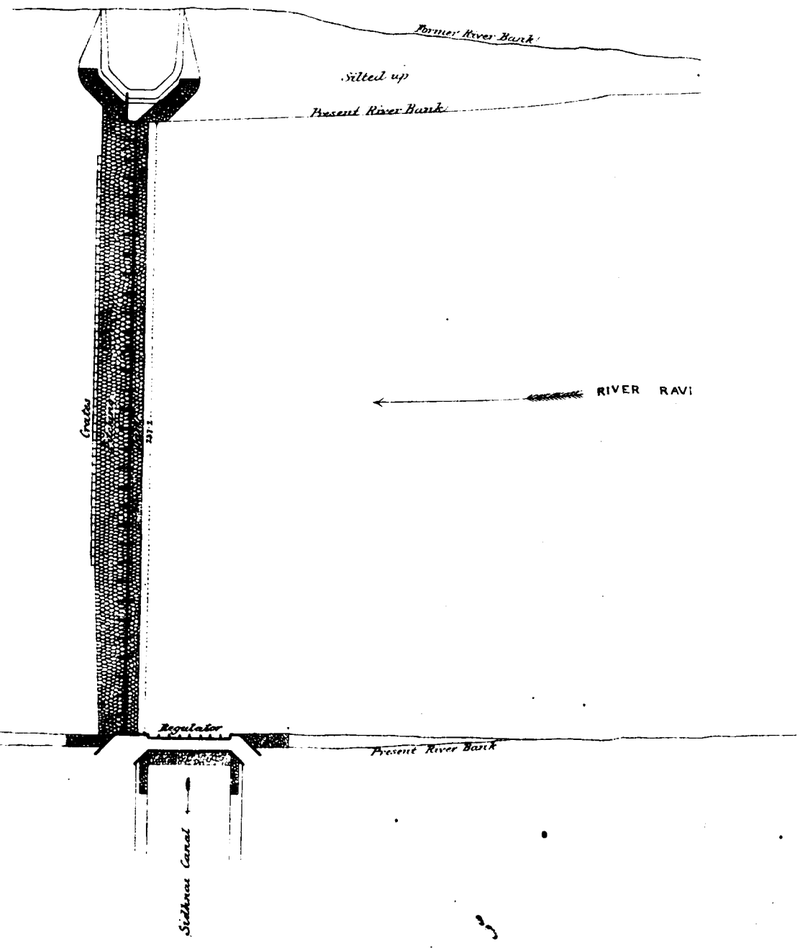
SIDHNAI CANAL

NEEDLE DAM AND REGULATOR AT HEAD

BLOCK PLAN

SCALE OF FEET





SCALE OF FEET.

SIDHNAI CANAL

REGULATOR AT HEAD

SIDHNAI CANAL-

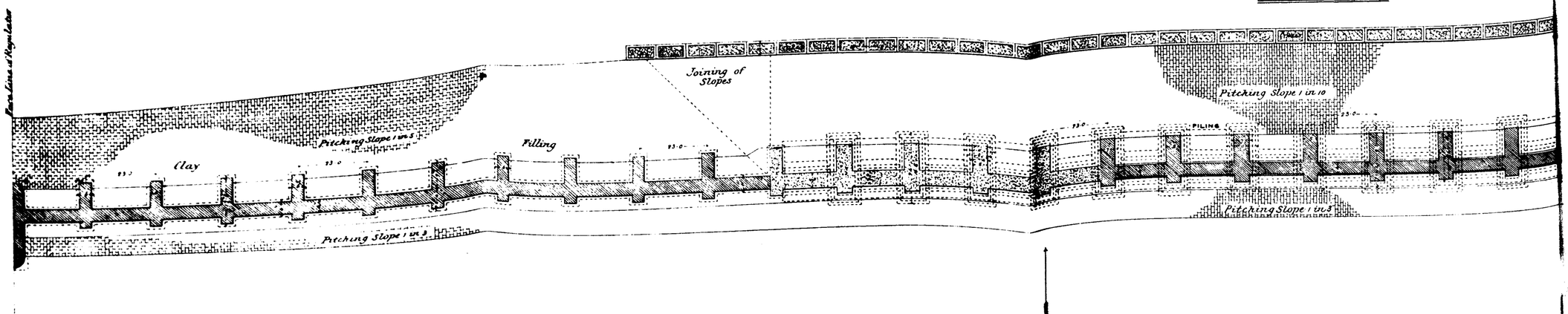
NEEDLE DAM AT HEAD

SCALE OF FEET

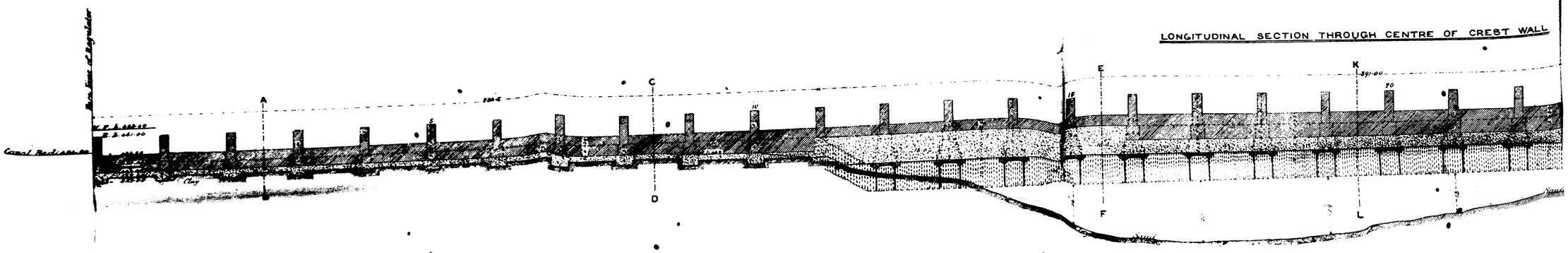
0 5 10 20 30 40 50 60 70 80 90

LENGTH OF DAM 737'2 FEET — 39 BAYS OF 20 FEET EACH

PLAN ON R.L. 450·00



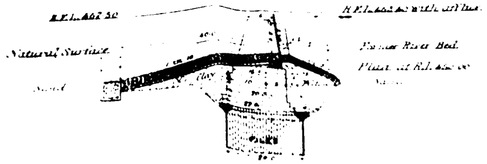
LONGITUDINAL SECTION THROUGH CENTRE OF CREST WALL



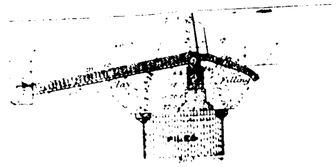
SECTION ON A.B.

SECTION ON C.D.

SECTION ON E.F.



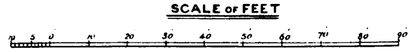
SECTION ON K.L.



SIDHNAI CANAL

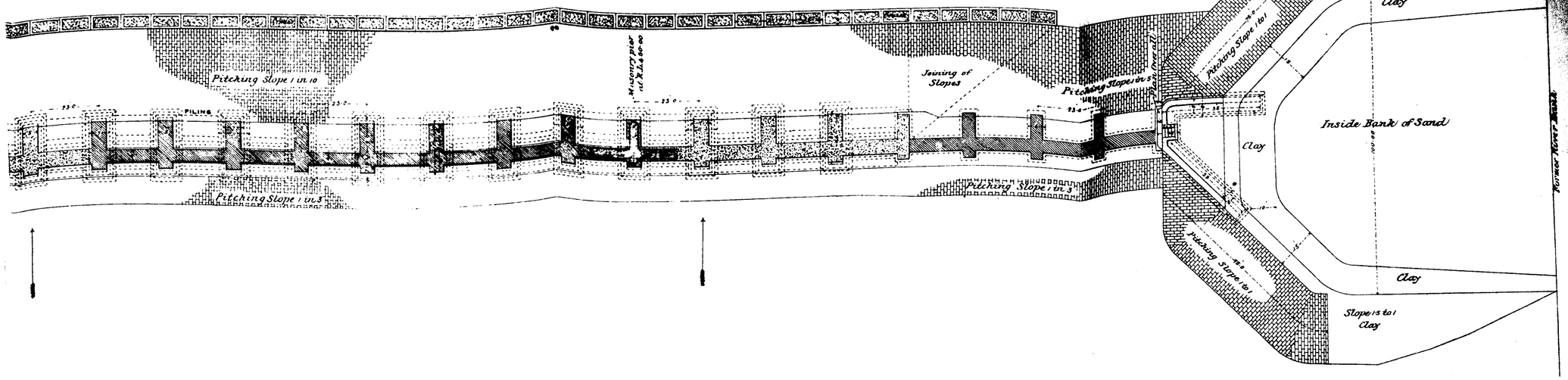
NEEDLE DAM AT HEAD

SCALE OF FEET

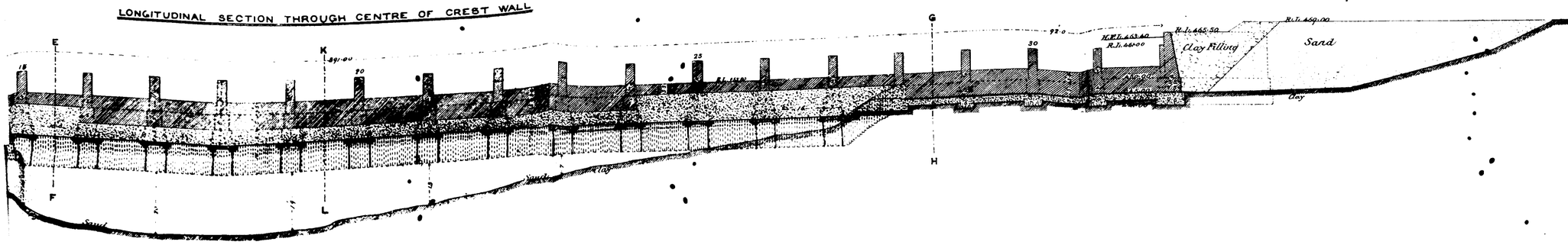


LENGTH OF DAM 737·2 FEET — 32 BAYS OF 20 FEET EACH

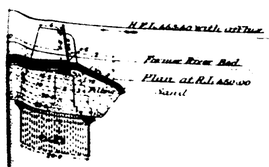
PLAN ON R.L. 450·00



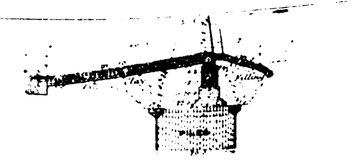
LONGITUDINAL SECTION THROUGH CENTRE OF CREST WALL



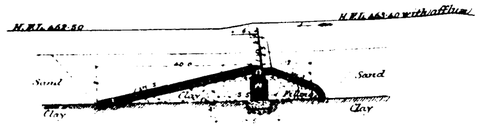
SECTION ON E.F.



SECTION ON K.L.



SECTION ON G.H.



L.V. Maclean
Executive Engineer
Punjab Irrigation Branch

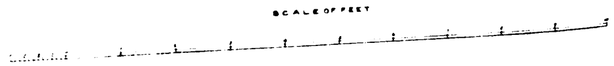
PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICE, CALCUTTA, DECEMBER 1882.

SIDHNAI CANAL

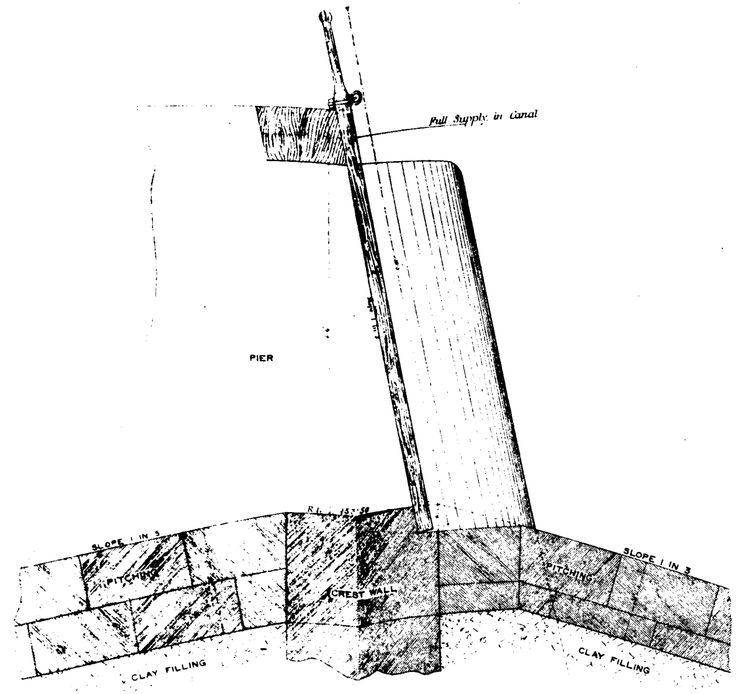
DETAILS OF

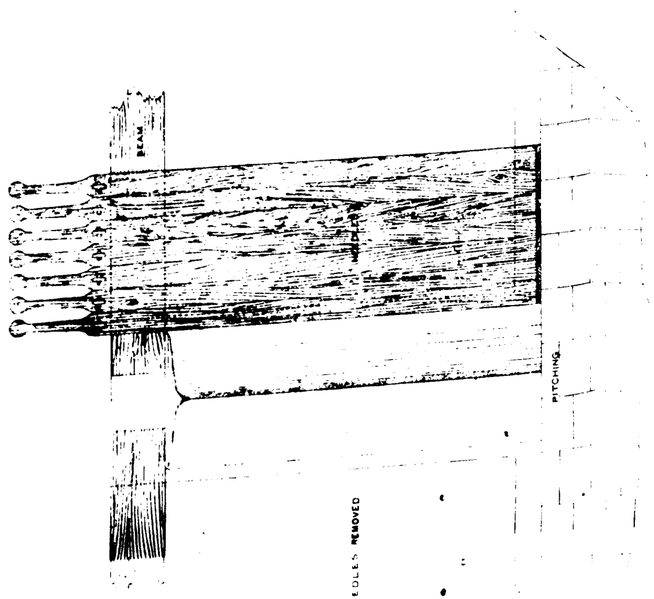
NEEDLE DAM AT HEAD

SCALE OF FEET

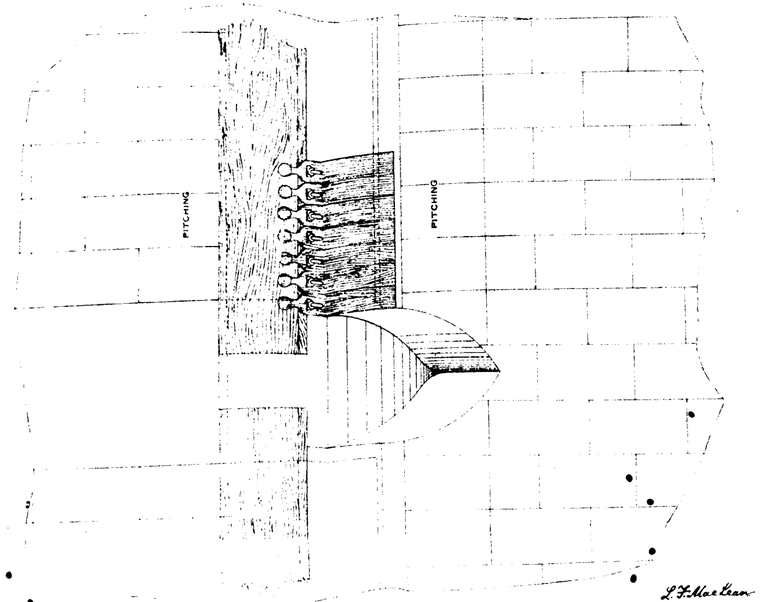


SECTION THROUGH CREST WALL





PLAN OVER ALL



L. F. MacLean
Executive Engineer
Punjab Irrigation Branch

PHOT. LITHOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, OCTOBER 1

SIDHNAI CANAL

DESIGN FOR

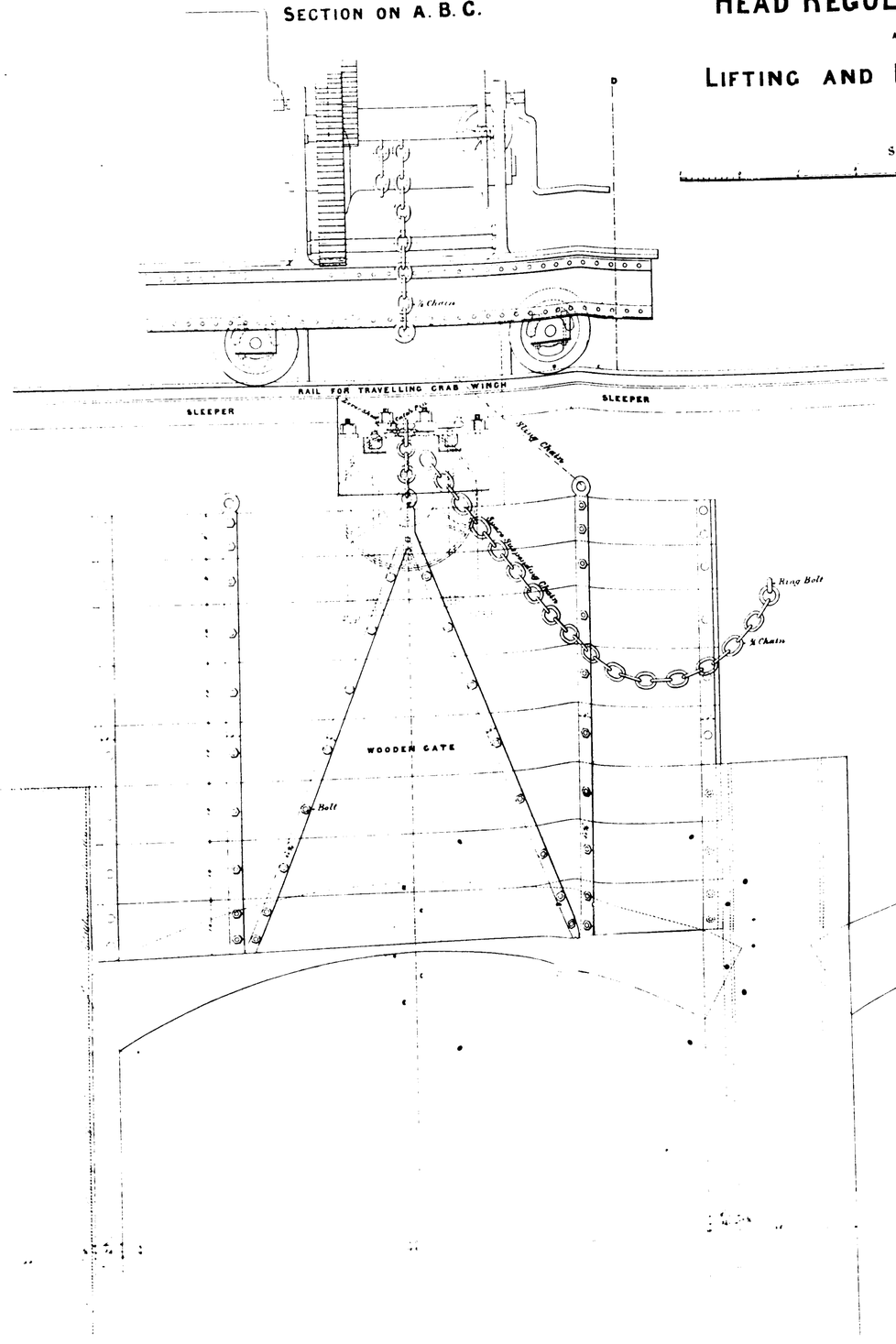
HEAD REGULATOR GATES

AND

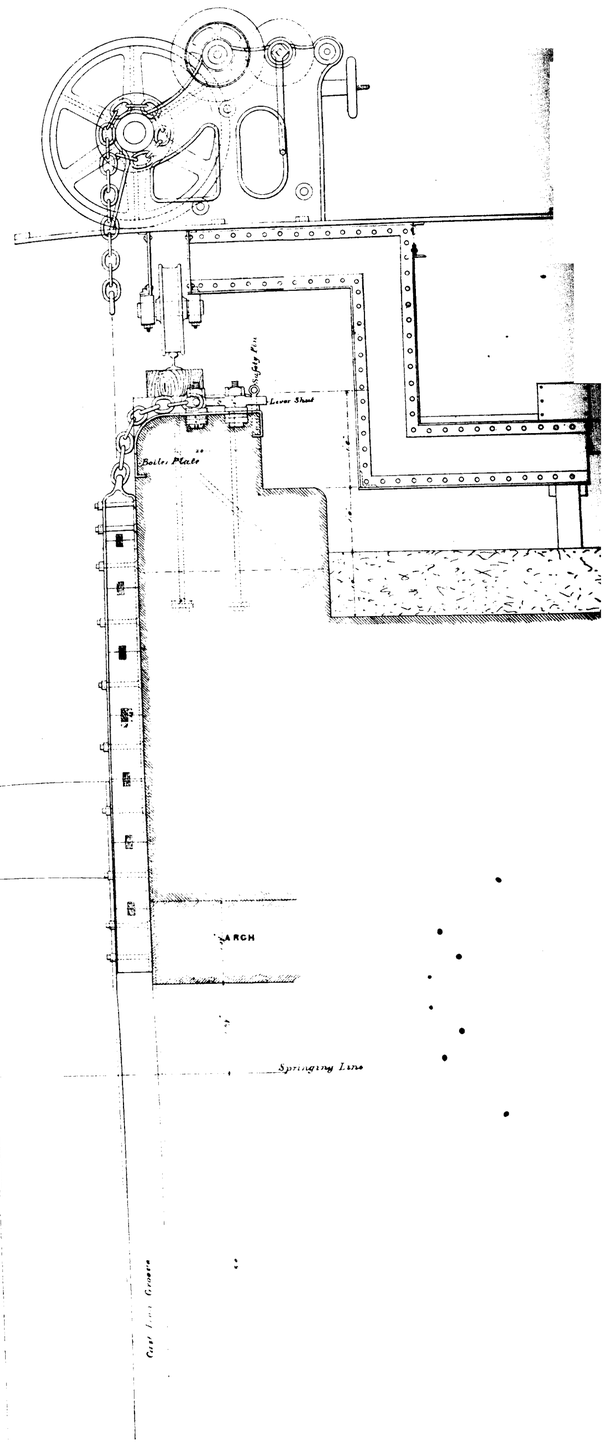
LIFTING AND HOLDING UP GEAR

Scale of feet

SECTION ON A. B. C.

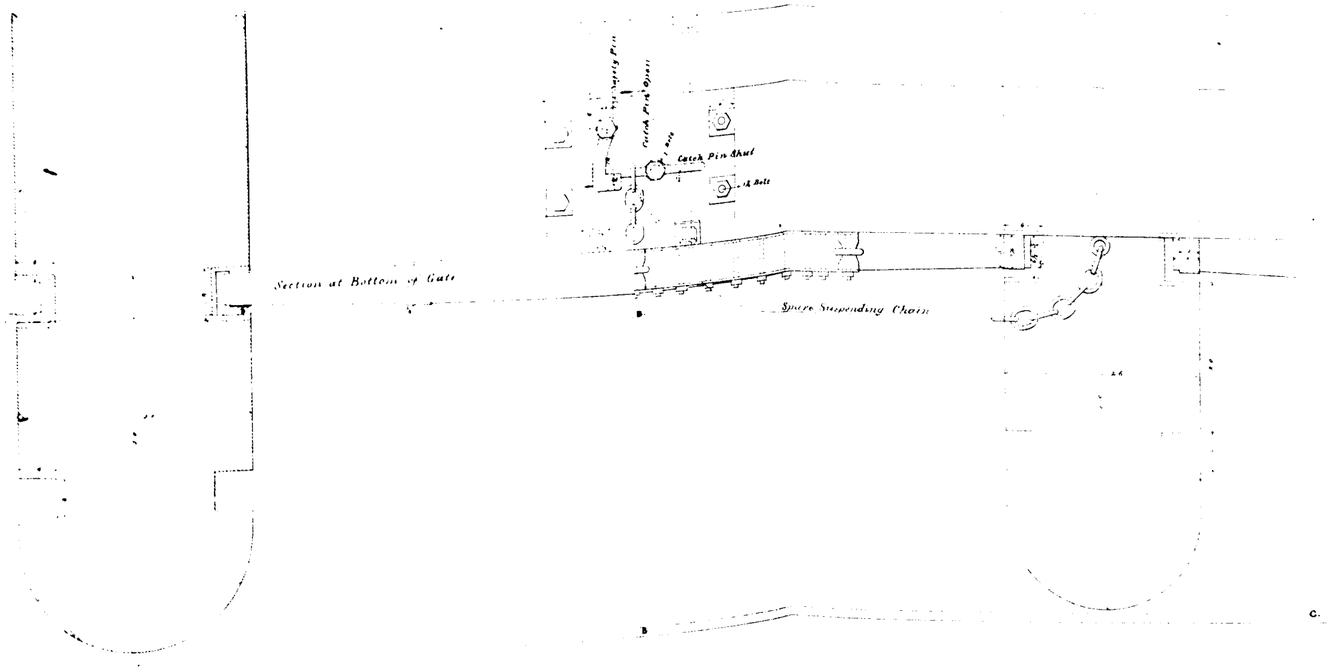


SECTION ON D. E. F.

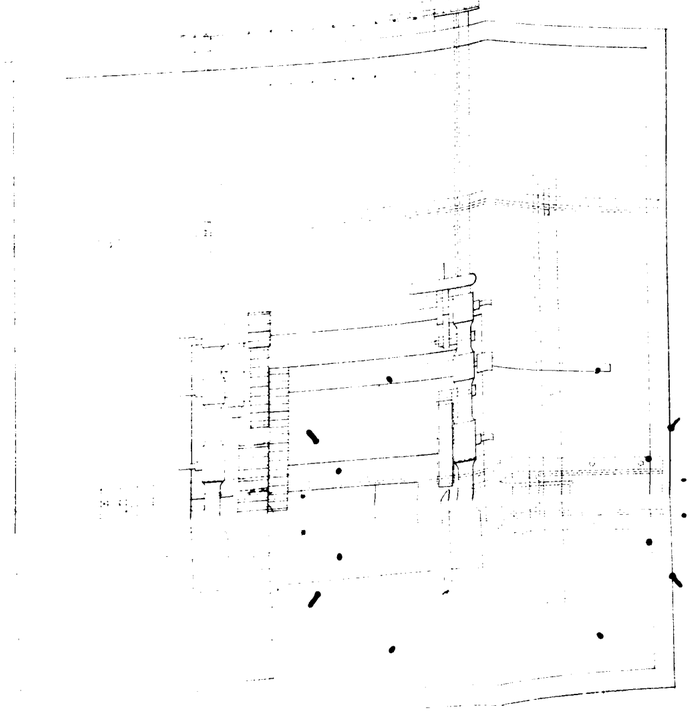


PLAN AT FLOOR LEVEL

PLAN AT PARAPET LEVEL



PLAN OF CRAB WINCH

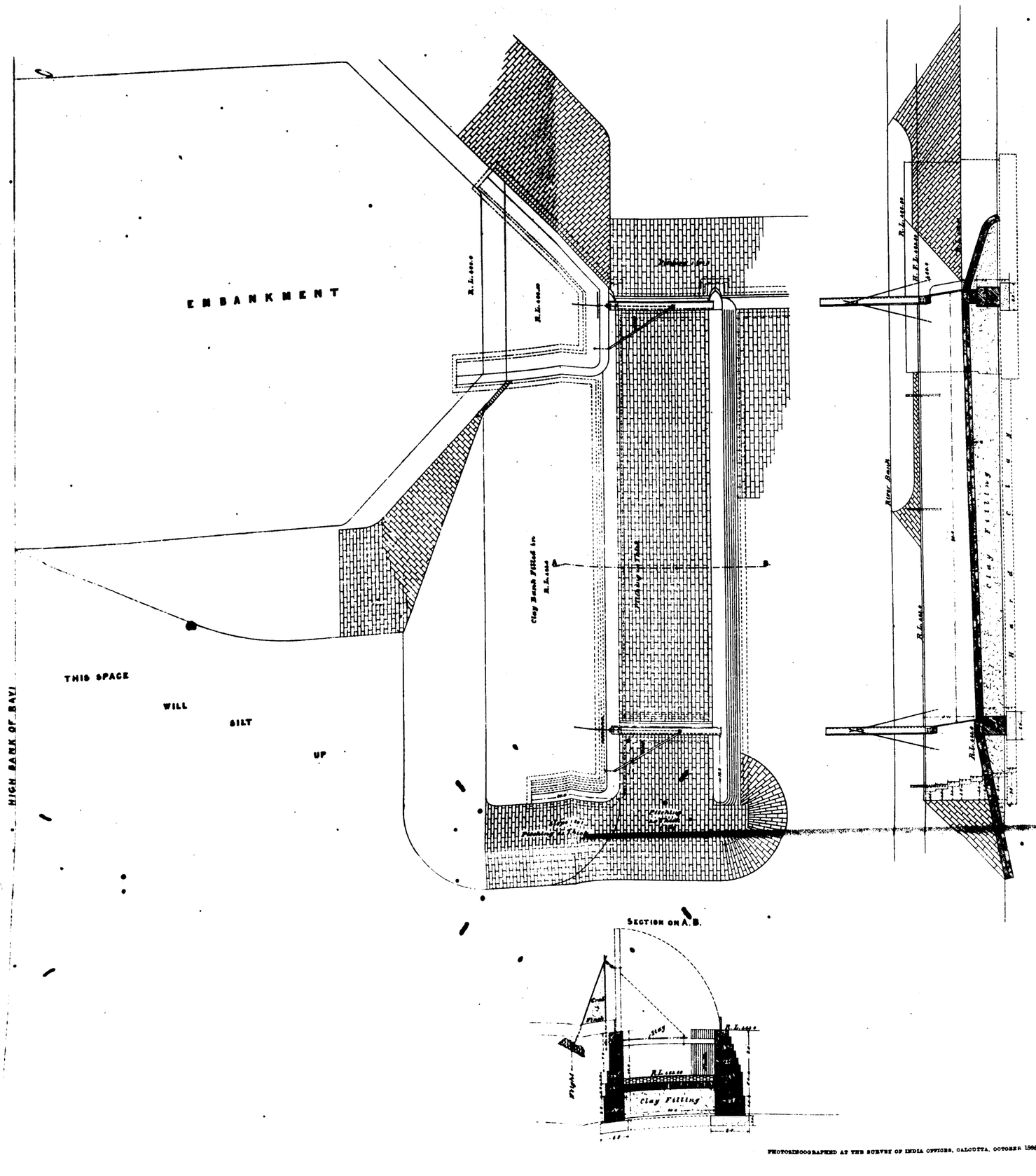


SIDHNAI CANAL DAM

DESIGN FOR

NEEDLE LOCK

Scale of feet



PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, OCTOBER 1898.

தமிழ்நாடு பாடநூல்க்காட்சிய நூலகம்,
எழும்பூர், சென்னை-600 008.

தவணைத்தாள்.

மே எண் : ப. எண் :

வழங்கிய நாள். (1)	திருப்பிய நாள் (2)	புதுப்பித்த நாள். (1)	திருப்பிய நாள். (2)

S.I. - 25/A 6 [illegible]