THE SILT QUESTION ON THE SONE CANALS.

A NOTE ON THE OPERATIONS OF THE FLOOD SEASON OF 1895.

By Mr. R. B. BUCKLEY,

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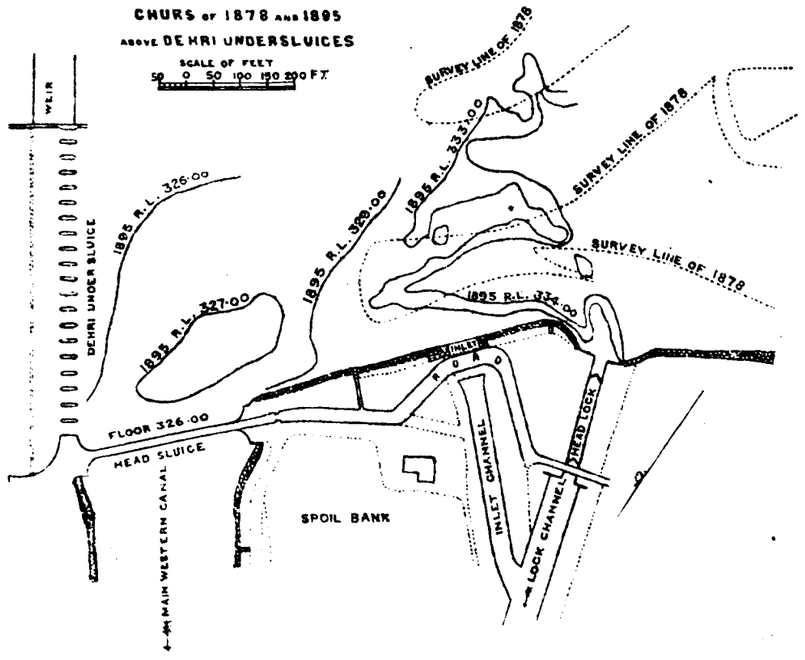
Ever since the Sone Canals were opened, some twenty years ago, there have been great difficulties with silt, especially at the heads of the Main Eastern and Main Western Canals just below the offtake from the river. The silt is deposited in the kharif season, which is the one of maximum demand for irrigation, and it has always been a question whether the deposits could be cleared out so as to ensure a sufficient discharge in the canals to irrigate the rice crop. On more than one occasion the canals have been nearly choked with deposits. A fleet of dredgers is employed. There are altogether eighteen steam dredgers and ninety-four mud punts on the Sone Canals. It was not an unusual thing for sixteen dredgers to be employed simultaneously, mostly near the heads of the canals, once at any rate in the year, in a desperate struggle to keep open a sufficient channel. The whole kharif crop was dependent on these efforts. A strike among the staff of the dredgers might have ruined 200,000 to 300,000 acres of rice and have necessitated large remissions of water-rates. An outbreak of cholera among the coolies who unload the mud punts might have done the same. The quantity of deposit cleared by steam dredgers from the first reaches to the two main canals has averaged about 7,000,000 cubic feet a year; and the total quantity cleared out both by hand and dredging in the same reaches has been about 11,000,000 cubic feet (Appendix No. 10). The cost of clearing the heads of these two canals has, on the average of ten years, exceeded Rs. 65,000 a year, exclusive of repairs and interest in plant. The cost of clearing silt from the whole of the Sone Canals used, in round figures, to be nearly a lakh of rupees a year, exclusive of repairs and interest on dredging plant (Appendix No. 11), and about Rs. 1,20,000 including those items.

2. During this year (1895-96), there has been a great change. No dredgers at all have been worked in the Main Western Canal (except in the lock channel) and only two for a short time in the Main Eastern. The dredging, in the first reaches of both canals instead of being 7,000,000 will be about 400,000 cubic feet; the total silt clearance both by dredging and hand will be about 750,000 cubic feet as compared with 11,000,000. The cost of clearing the heads of the two canals will be less than Rs. 7,000* as compared with the average of Rs. 65,000. The total cost of silt clearance from the whole of the Sone Canals will be about Rs. 16,000 as compared with the average of nearly a lakh of rupees.

3. These results have undoubtedly been obtained, to a large extent, by the measures which have been adopted to check the deposits. But, on one side of the river, these measures have, I think, been assisted by the action of the river itself. A large sand-bank, which is shown in the following sketch, has formed above the head sluice at Dehree:—



* This figure includes the pay of a large establishment which had to be entertained on the dredgers although no work was done.

A somewhat similar bank formed in 1878. This bank, by checking the velocity in front of the head sluice, has probably decreased the amount of sand carried into the canal. On the other side of the river, where the results obtained have been satisfactory, but not quite equal to those on the Dehree side, there is no such bank.

4. The measures which have been adopted to check the deposits of silt have been—

I. An alteration in the method of working the under-sluices.

II. An alteration in the closure of the head sluice when the river was in flood.

III. An alteration in the system of admitting the supply through the head sluice.

IV. The reduction of the capacity of the channel to the maximum discharge required.

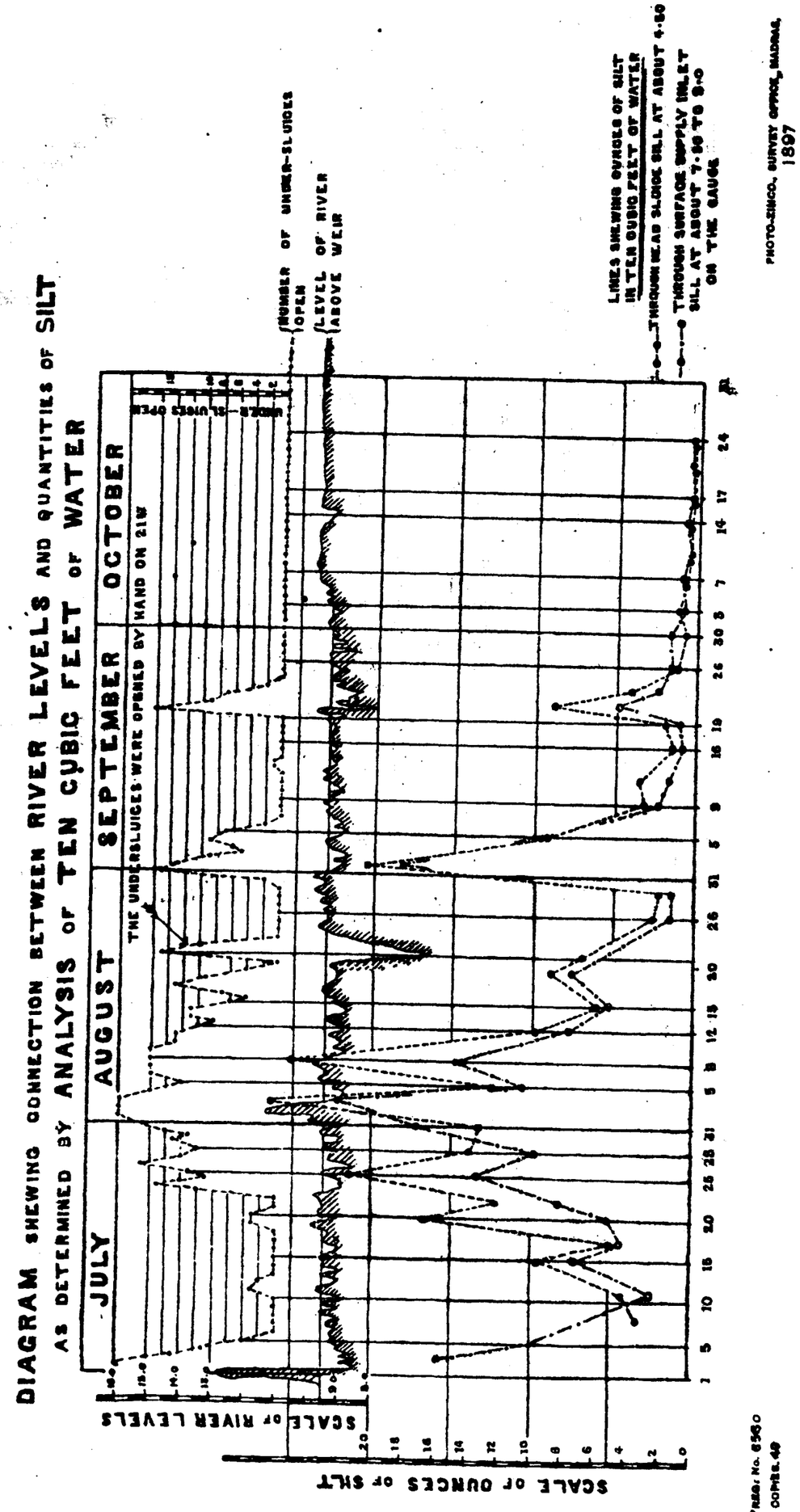
V. The introduction of a system of flushing when the condition of the river was suitable.

VI. The working of a 'scoring fleet' in the Main Eastern Canal.

VII. The construction of a surface supply inlet at Dehree.

5. I propose to discuss these different improvements in order; but it will be best to explain, first, that the main difficulty on the Sone Canals has been the choking of the heads by sand. The deposit in the first half mile or so of the Main Western Canal used to be almost pure sand; there was little or no mud. The sand immediately below the head sluice was very coarse, and there were large numbers of pebbles in it, some the size of a man's thumb. A great deal of this deposit was too coarse to have been held in suspension in the water of the river generally: it was matter which was travelling along the bed of the river very possibly, but such as could only have been lifted from the bed by a velocity considerably in excess of the ordinary velocity of the stream. Appendix No. I is a statement which shows that, on the average of five years, 2,300,000 cubic feet of material were taken out of the first-half mile of the Main Western Canal every year. The canal is 180 feet base, and this quantity amounts, roughly, to a wedge of sand 7 feet thick at the head and 2 feet at the half mile. The deposit was always greatest near the head. The same statement shows that the amount of deposit in the Main Eastern Canal (80 per cent. of 3,050,000) was much about the same. This fact is interesting, and it contains an important lesson. The Main Eastern Canal has a maximum discharge of 1,600 cubic feet: the Main Western carries 4,000 cubic feet. The base of the Main Eastern is generally 80 feet, that of the Main Western is 180. But the first quarter mile of the Main Eastern is cut to 180 feet base, the same as the Main Western. It was in this broad quarter mile that the great majority of the deposit was found. The broad portion was a silt trap which fulfilled its purpose of catching the silt only too successfully. It was noticed that the material excavated from this silt trap certained a good deal of mud, much more than the material excavated in the corresponding part of the Main Western Canal, where the deposits were almost entirely sand. It will be seen by reference to Appendix No. I that, during the silting months, the discharge of the Main Western Canal is two-and-a-half times that of the Main Eastern, yet the deposit at the head is no greater, but approximately the same. Why is it that the greater discharge does not bring the greater deposit? The answer is—because the greater discharge, in the same sized channel, means a higher velocity, and the higher velocity carries forward material which, in the lower velocity, is deposited. In other words, the Main Eastern Canal was too large. The matter will be again referred to in paragraph 13.

6. I will now consider, one by one, the various changes which have been made:—



I.—AN ALTERATION IN THE METHOD OF WORKING THE UNDER-SLUICES.

There are 20 under-sluices 20 feet broad on either flank of the weir and 16 in the centre of it. It has always been the custom to keep the vent next the abutment—that is the one nearest to the head-sluice—constantly open during the silting season. The other under-sluices used to be worked according to the condition of the river, with, perhaps, preference for keeping the sluices near the abutment open more than the others; the object being to keep a good stream along the face of the head-sluice, with the idea, I presume, that this kept a good channel open. The result of this system, I think, was to keep a volume of coarse sand flowing along the floor in front of the head-sluice: this sand was kept in a state of agitation by the current, and was, therefore, the more readily drawn into the canal.

7. This year the first four vents of the under-sluices have been kept closed as much as possible and the other vents have been worked so as to keep the river level as high as possible. The smaller the velocity of the water past the head-sluice the better, I think, provided of course a sufficient channel is maintained in the river. The quieter the water is the less sand there will be in it, and consequently, the less will pass into the canal. In order to keep the first four shutters up stonger links were put on the chains which support the lower shutters. One result of this was that on the Baroon (Eastern Main) side of the river a deposit of silt occurred in the river on the upstream side of the head-sluice; this was deepest at the upper end of the sluice: there was the same thing, but on a smaller scale on the Dehree side. To what extent this method of working the under-sluices affected the silt drawn into the canals it is impossible to say, but the diagram which faces this page seems to indicate that the silt is very much greater when the under-sluice gates are open than when they are closed.

8. The diagram needs some explanation. The shaded line in the centre of the diagram shows the level of the river above the weir. The floods of the 1st July and 2nd August, which rose to 12·80 and 11·35 on the gauge, respectively, display themselves plainly. Otherwise the line shows only insignificant fluctuations. But these insignificant fluctuations of a few inches above or below 9·50 on the gauge affect the under-sluice shutters materially. These shutters will stand at about 9·50, but they fall automatically as soon as the river rises above that level unless they are fixed, and they cannot be readily lifted until the river falls below 9·00. Consequently, a rise of three inches in the river may cause all the under-sluice shutters to fall, and thus produce a rapid stream where previously there had been but little current, and this stream continues until the river has fallen considerably. The line at the top of the diagram shows the number of under-sluice shutters open, and it gives expression, in a more marked way, to small rises of the river. Thus, from the 23rd to the end of July, it will be seen that the under-sluices were constantly being pushed open by small rises in the river as soon almost as they were closed. The two dotted lines which are given at the bottom of the diagram express the number of ounces of slit in ten cubic feet of water drawn into the Main Western Canal (Appendix No. 9): they illustrate the amount of silt in the river water. It will be seen at once that the big floods carry a large quantity of silt. That is well known. But the point in the diagram which is most interesting is that small rises of the river, when they open a large number of under-sluices, increase the amount of silt carried in the water very materially even when they rise only a few inches, and when the condition of the river generally can hardly have been very different from before. Thus, on the 20th July when four under-sluice shutters went down, there was a marked rise in the silt line; it fell again on the 22nd, when the under-sluices were all closed, but rose rapidly on the 25th, when 12 under-sluices were down although there was a rise of only a few inches in the river. A careful study of the diagram shows similar cases. It would seem then that the amount of silt in the water depends, to no small extent, on the number of shutters which are down, that is on the strength of the current, and that it is, when the river is about 9·50, far more dependent on the current than on the amount of flood. I think this is strong evidence that it is desirable to keep the under-sluices near the head-sluice closed as much as possible.

9. The next matter is—

II.—AN ALTERATION IN THE CLOSURE OF THE HEAD-SLUICE WHEN THE RIVER WAS IN FLOOD.

It has hitherto been the rule to close the canal entirely when the river rose to 12·0 in the gauge (338·00) and to open the canal again when the flood fell to the same level. There is no doubt that if this had not been done, the canals would have been choked entirely sometimes. There is much more silt in the water of a river when the flood is rising than when it is falling. It occurred to me that it might be very advantageous to close the canals early when a flood was rising and, if necessary, to open them when the river was at a higher level than that at which they had been closed. The following statement shows the number of days the Main Western Canal would have been closed during the last eleven years had the head-sluice been shut when the river rose to 10·0 on the gauge (336·00) and opened when it fell to 11·00 (337·00):—

Year.	July.	August.	September.	October.
1	2	3	4	5
1884	1	5	..	..
1885	..	6	2	..
1886	..	..	1	1
1887	2	5	..	..
1888	1	4	..	..
1889	..	4	..	..
1890	..	2	..	..
1891	..	..	..	..
1892	1	..	..	..
1893	..	..	5	..
1894	1	3	..	1

Closures of five and six days in August might have proved inconvenient, as the rice is then being transplanted, but the closures in the other months would have hurt no one. I decided to close the Main Western Canal this year, not at 10·0, but at 10·50 (336·50), and to open it at 11·00 (337·00). A set of rules, which will be found in Appendix No. 2 were drawn up. The actual result of them this year was that the Main Western Canal was closed as shown below:—

Year.	June.	July	August.	September.	October.
1	2	3	4	5	6
	HOURS.	HOURS.	HOURS.	HOURS.	HOURS.
1895 ..	10½	6½	21½	..	..

with no inconvenience at all to any one. On the Baroon side of the river the flood level is higher and the levels fixed were 10·50 (336·50) for closing the head-sluice and 11·50 (337·50) for opening it. The result was that the Main

Eastern Canal was closed on two occasions on the 30th June and on the 1st of August:—

Year.	June.	July.	August.	September.	October.
1	2	3	4	5	6
	HOURS.	HOURS.	HOURS.	HOURS.	HOURS.
1895	10½	10½	39	..	..

without any inconvenience. In this case also it is not possible to measure the effect produced by the change, but the facts which are expressed in Table A of Appendix No. 9 show how greatly the silt in the water increases in a flood, and, consequently, the desirability of closing the head-sluices on these occasions.

III.—AN ALTERATION IN THE SYSTEM OF ADMITTING THE SUPPLY THROUGH THE HEAD-SLUICE.

10. It is here that the most important change has been made. The head-sluices on either side of the river are alike. They have each 24 vents of 6 feet wide and 9 feet high. There are two shutters in each vent, one on the top of the other. Until last year some of the lower shutters were 4½ feet and some were 3 feet high. They have now all been made 4 feet 6 inches high, that is the top of the lower shutters are 4 feet 6 inches above the floor level. It used to be the custom, when regulating the discharge through the head-sluices, to open as few shutters as possible, and to open those fully, or, rather, to open as many shutters fully as were required, and to open one more partially, to regulate the discharge. It was never the custom to open all the 24 shutters a little, but to open as few as possible and to open those few as much as possible. The shutters which were opened were, as a rule, contiguous ones. It seemed to me that this system was not good. It created a maximum draught at a particular point: this draught created a disturbance in the water and drew up from the bed of the river the pebbles and large sand which were being drawn along it by the stream created by the under-sluices. The fact that pebbles the size of hen's eggs were thrown into the canal over the 3 feet or 4½ feet of the lower gates is, to my mind, strong confirmation of this theory. These pebbles cannot possibly have been in the water; they must have been on the bed of the river. If the commotion and up-draught caused by the draw of the sluices was sufficient to lift these pebbles, it was, of course, sufficient to lift up the coarse sand which travels along the bed of the river and which has been the cause of all the trouble at the head of the canals.

11. Arrangements were therefore made for opening all the 24 upper shutters to the utmost and for regulating the discharge by 'kurries' placed in the groves over the top of the lower shutters. This was done on the Dehree side in the Main Western Canal. On the Baroon side (Eastern Main Canal) the same arrangement was in force; only the regulation was effected by planks put in the iron frames which I had fitted in the previous year for the wire screens which proved a failure. On the Dehree side the new surface supply inlet was also used. This was constructed experimentally last year. It is an inlet at a high level which takes 18 inches to 2 feet in depth off the surface of the river; so, practically, the alterations made in the head sluices amounted simply to making arrangements for drawing the supply from the highest levels possible.

12. Appendix No. 3 is a statement which shows the level of the sill over which the water was drawn into the Main Western Canal every day from June to October 1895, both through the head-sluice and the inlet. It will be noticed that during the greater part of July, August and September the supply was

taken through the head-sluice over a 6·50 sill and through the inlet over a 7·50. Previously the supply was drawn (as described in paragraph 9) over a 4·50 sill. There is no question that this change has had an enormous effect. It equalises the draft on the river over a long line of vents instead of the draft being concentrated on a few vents and the water runs smoothly into the canal instead of creating eddies which left the heavy sand from the bed of the river.

IV.—THE REDUCTION OF THE CAPACITY OF THE CHANNEL TO THE MAXIMUM DISCHARGE REQUIRED.

13. The first quarter mile of the Eastern Main Canal was far too large. It was 180 feet base. I reduced the bed width to 100 feet and deliberately left about $2\frac{1}{2}$ to 3 feet of sand in the bed of the reduced channel. The deposit which was left in the bed extended rather more than half a mile; it was a 'silt wedge' 3 feet thick at the head-sluice tapering off to nothing at about $\frac{5}{8}$ mile. The waterway of the channel at full supply level was reduced, in the first quarter mile, from nearly 1,800 square feet to about 800 square feet. The result has been eminently satisfactory. Last time this quarter mile was cleared 2,475,000 cubic feet of silt was removed * by dredging and hand clearance. This year at the end of the silting season only about 110,000 cubic feet had been deposited in the first quarter mile, and it is not absolutely necessary to remove this at all. This result is not due entirely to the restriction of the channel: if the head-sluice had been worked as it was formerly worked I doubt if it could have been possible to have dredged fast enough to keep down the heavy sand which would have been swept in from off the river bed. But the manner in which the sluice was worked this year, has stopped that action, and a good deal of the finer sand which does still come in and all the mud has been carried forward by the higher velocity, which is kept up in the restricted channel. I intend next year to restrict the channel still more, this will be advantageous, I hope, as it will result in a deeper channel. The present one, though suitable for irrigation, causes some trouble, in the dry season, to navigation.

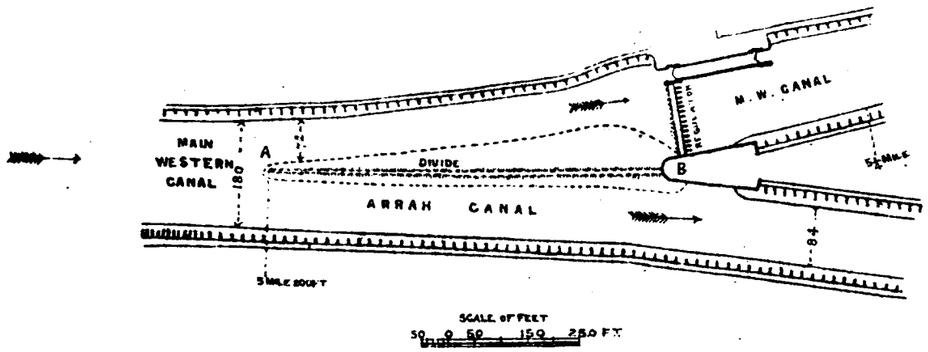
14. No restriction has been made to the head of the channel of the Main Western Canal: the discharge is nearly three times that of the Main Eastern. But, at the regulator, at 5 miles 900 feet of the Main Western, I have constructed a 'Divide' which has given very satisfactory results. Above and below the regulator the Main Western Canal has an enlarged section. There has always been a large quantity of dredging and also silt clearance by hand at this point. This table gives some facts:—

—	Average of six years 1889–90 to 1894–95.	
	Dredging.	Hand clearance.
1	2	3
	C. FT.	C. FT.
Above regulator	936,000	43,000
Below do.	465,000	54,000
Total ..	1,401,000	97,000

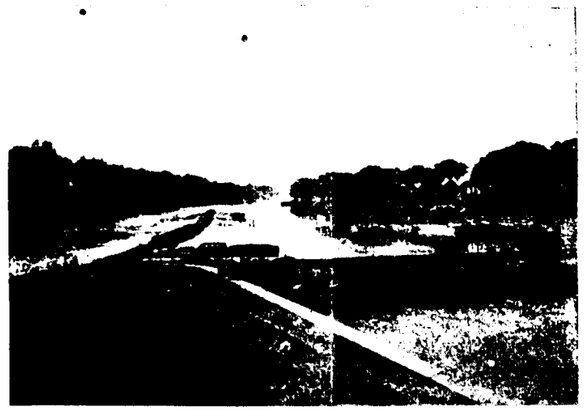
that is, an average of about 1,500,000 cubic feet of silt has been cleared at this point at a cost of Rs. 9,000 a year approximately. The silt was all pure mud: no sand. It is material which would be easily carried forward by a velocity of $2\frac{1}{2}$ feet a second, or even less. Appendix No. 4 is a note I wrote in May last, when I determined to construct the 'Divide;' it explains the matter

* That is dredging in the silting season of 1893 and hand clearance in the closure of 1894.

more fully. The following sketch shows what was done. The 'Divide' is simply an embankment in the centre of the Main Western Canal which produces the nose between the two canals, so that the waterway is restricted to that which is suitable to the discharge to be passed; in other words the 'Divide' produces the two lower canals upstream until their respective bed widths meet.



The following photograph was taken from the spoil bank on the nose below the point B. It is taken looking up the Main Western Canal :—



There used to be, it is said, a difficulty in former years in sending a sufficient supply through the regulator. I do not understand how the difficulty arose, but before the 'Divide' was made some fears were entertained that it might interfere with the allotment of the supply between the two canals. It has not done so: the results obtained have been most satisfactory. On the Arrah Canal side of the 'Divide' the restricted channel has scoured slightly: on the other side of it silt has been deposited somewhat as shown in the dotted line of the sketch, but there is an amply sufficient channel, the lowest point of which is below normal canal bed level, to carry the full discharge which is required. It has not been necessary to dredge at all this year either above or below the regulator except a little in front of the lock, and I have now no doubt that dredging and silt clearance at this point will be unnecessary in future. The 'Divide' has cost about Rs. 1,300, and I may probably spend another Rs. 700 on it—Rs. 2,000 in all.

15. The silt still deposits above the lock and in it. After the kharif season was over I fastened back all the lock gates for three days, and ran the discharge through the lock with a velocity of about 7 feet per second. This removed the silt in the lock and some below it, but did not materially affect the deposits above the lock. I contemplate the construction of a light needle weir in the lock, so that it will be possible to run the discharge through it without interfering with the regulation of the canal. This will help to maintain a channel above and below the lock.

V.—THE INTRODUCTION OF A SYSTEM OF FLUSHING THE CANAL WHEN THE CONDITION OF THE RIVER WAS SUITABLE.

16. The deposits of silt in the first five miles of the Main Western Canal (above the bifurcation of the Arrah Canal) have been measured three times a month this year from the 15th June. The figures are given in Appendix No. 5 mile by mile; and the total quantity in the five miles is plotted on the diagram on the opposite page : the discharge of the canal is also shown on the diagram.

17. During the silting season (June, July, August, September) three flushes were run down the Western Main Canal. Appendix No. 6 is a note written in August on the July flush : it explains the reason why these flushes were run and states the results of one of them. The following table gives the main facts of each of the flushes :—

Date of flush.	Discharge.		Silt in the first five mile—		
	Minimum.	Maximum.	Before the flush.	After the flush.	Net result.
1	2	3	4	5	6
	C. FT. PER SEC.	C. FT. PER SEC.	C. FT.	C. FT.	C. FT.
20th to 23rd July	2,330	4,153	5,667,200	5,221,700	— 445,500
16th to 20th August	2,441	3,753	6,579,540	5,609,340	— 970,200
17th to 20th September ..	2,452	3,592	4,909,520	5,003,460	+ 93,940

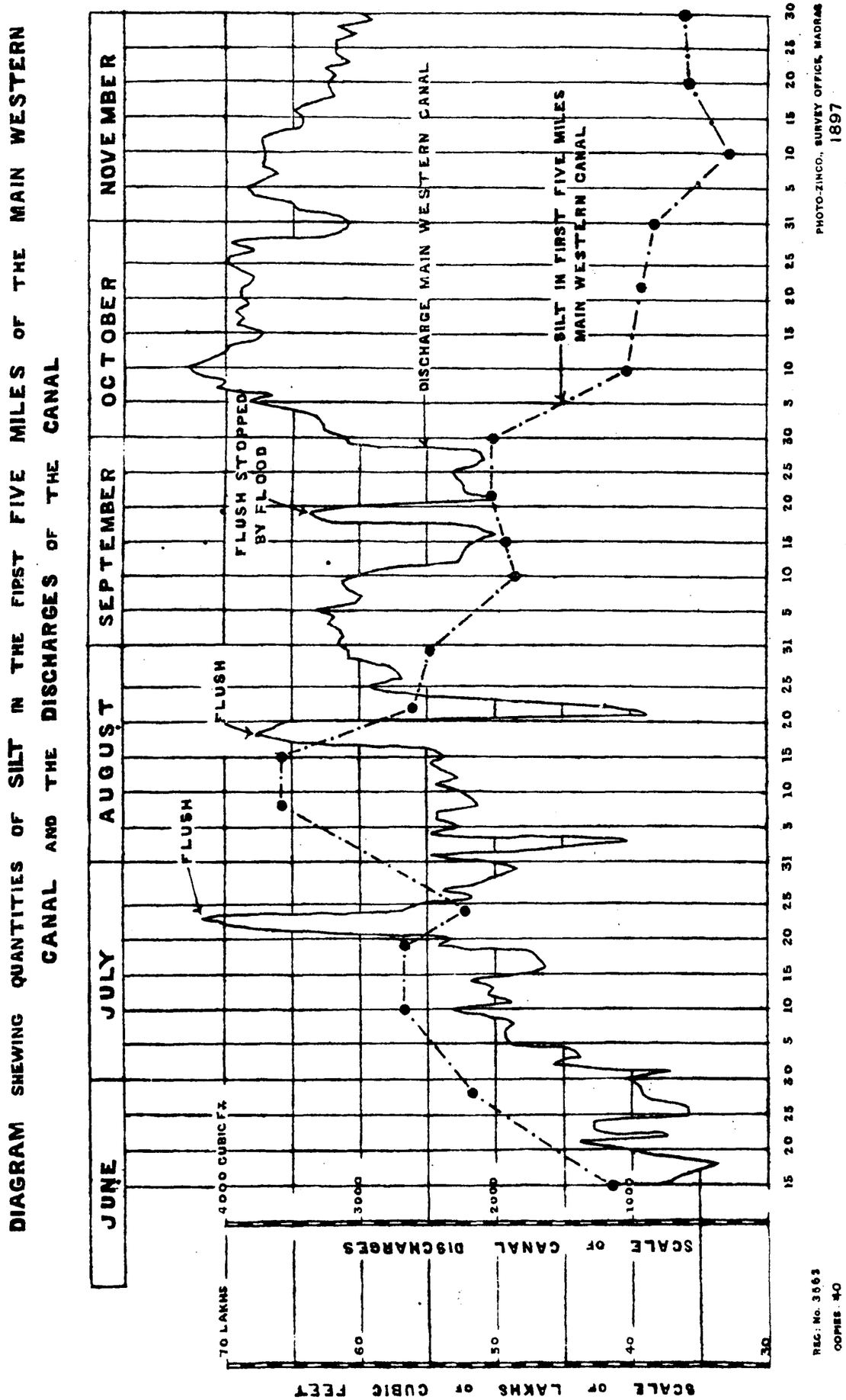
The third flush was stopped by a flood in the river, and it was not worked up to the maximum discharge : this was unfortunate. Some care was necessary in running these flushes to ensure the safety of the canal.

18. Only one flush was run in the Eastern Main Canal during the silting season: it ran from the 22nd to the 27th of August. The results were :—

Discharge.		Silt in first two miles—			
			Befor the flush.	After the flush.	Net result.
1	2	3	4	5	6
Minimum.	Maximum.		C. FT.	C. FT.	C. FT.
1,518	1,721 ..	1st mile ..	897,600	875,600	— 22,000
		2nd mile ..	469,920	398,640	— 71,280

So that about a lakh of cubic feet of silt was removed in five days, mostly from the second mile. The reason why the silt was scoured from the second and not from the first mile is that the first mile contains mostly sand which I deliberately left in the bed in 1894, but in the second mile there is more mud which has been deposited this year. This mud was washed away during the flush. Appendix No. 7 shows the quantities of silt in the first two miles of the Eastern Main Canal : there is practically no silt below the second mile-stone in the bed of this canal. It will be noticed that 275,000 cubic feet of dredging was done in the first mile of the Eastern Main Canal : this was done as a precaution, but I think, now, that it was quite unnecessary.

19. The results which have been obtained by these flushes are satisfactory in themselves, since a material reduction has been made in the silt in the



canals. But the lessons which have been learnt from then are far more important. These lessons are—

(i) That the Main Western Canal will carry about 30 per cent. more water than has been generally supposed and that, for large discharges in it, N., in Kutter's formula, may be taken as 0·020.

(ii) That, consequently, a considerable volume of silt may accumulate in the canal without impediment to the discharge of the maximum of 4,000 cubic feet per second.

(iii) That, when the river is steady at a moderate level, the introduction of the maximum discharge into the canal does not increase the deposit of silt in the canal, but the contrary. This is so even when the water in the river is particularly muddy.

(iv) That the Dehree head-sluice (with the lower shutters down) is too small to admit the full discharge of the canal (4,000 cubic feet), unless the river is at 9·60 to 10·00 on the guage (335·60 to 336·00), and that it is only under very exceptional circumstances that the river can be kept at that level during July, August and September.

20. With reference to (i) and (ii) it is only necessary to say that the silt which has accumulated this year in the Main Western Canal is almost entirely in silt berms. The deepest part of the bed, in the first four miles at any rate, has scoured. This same action has been going on for years in the first reach of the Patna Canal (see paragraph 4, Appendix No. 6). I am satisfied that there is no necessity at all to remove the present silt berms from the Main Western; they are quite small.

21. The fact (iii) that a large discharge in the silting season actually reduces the deposit is important. It proves that if the discharge of the canals during that season is adjusted, with judgment, according to the condition of the river (as well as in accordance with the necessities of irrigation), it may be possible to prevent all deposits of muddy silt. This result would be advantageous, not only as regards the channels themselves, but also as regards the fields. The muddy silt does harm in the canal, but good to the crops; if it is not deposited in the canal, it goes on to the fields. I propose next year to institute a system of flushes to be run in July, August and September, whenever the river is favourable. What is required is a steady river at about 9·30 to 9·50 on the gauge (335·30 to 335·50) with as many under-sluice shutters up as possible. When a small supply is being taken for irrigation a flush in the Main Western Canal necessitates a good deal of arrangement. The rules in Appendix No. 8 were drawn up to guide the Executive Engineers of the three Divisions concerned. These may require some modification next year.

22. It is interesting to study the diagram which faces page 8 of this note. It shows graphically how the silt increases with a small discharge and diminishes with a large one. From the 15th June to the 20th July the discharge of the canal was small: the silt rapidly increased. The flush from the 20th to 24th July produced a reduction; the comparatively small discharges from the 28th July to 15th of August caused an increase of silt, which is shown at that time. The flush of 16th to 20th August caused the sudden drop in the diagram, and the comparatively large discharges from the 25th August to the 10th September reduced the silt in the canal. During the latter part of September the silt in the water was less than before, so there was but little deposit. In October and November there was hardly any silt in the water, and the large discharges produced the reduction of the deposit in the canal which is shown in the diagram.

23. It seems clear that large discharges are beneficial when the condition of the river is suitable. Certainly they are so as regards all deposits which occur below the first mile of either of the main canals. But, if sand were brought in by the water, such discharges would not be beneficial, as the sand would drop in the first mile. How far the good results, in that respect, which have been obtained this year, are due to the chur on the Dehree side I am not prepared to say.

24. The fact (iv) that the Dehree head-sluice is too small is proved by the fact that in two out of the three flushes it was not found possible to get in the full discharge of 4,000 cubic feet per second over the top of the lower shutters. It would have been necessary to lift the lower shutters to obtain 4,000, and that would have

choked the canal with sand. During nearly the whole of October (see Appendix No. 3) the maximum discharge which could be drawn into the canal (without opening the lower shutters) was drawn off the river; but it only exceeded 4,000 cubic feet in five days. At that time the whole of the under-sluice shutters were closed, and the water was drawn off a still pool, the level of which varied from 9·60 to 9·95 on the gauge, and is not possible to keep it higher. It is rather an interesting fact that a larger discharge can be got into the canal, with the same river level, when some of the under-sluice shutters are open. The stream which the open under-sluices create is not at right angles to the canal apparently, but somewhat oblique to it, and the velocity of approach increases the discharge through the head-sluice.

25. The chief reason why the full discharge of 4,000 cubic feet can rarely be obtained is that it is difficult, and possibly dangerous, to lift the front under-sluice gates when the river is above 8·80 or so. The men do not like it, and the shock is severe. Consequently, if it so happens that the river, naturally, keeps at about 9·00 on the gauge, it is not practicable to get it higher until it has fallen lower. Thus there may be times when for ten days or more it is not possible to get in more than 3,500 to 3,700 cubic feet into the canal, even when it is clean. Luckily the river is almost always fairly steady in October, when the maximum demand arises, so that, at that time, the necessary discharge can be obtained. It might be, however, that a demand for 4,000 cubic feet might arise in August or September, when it might not be possible to satisfy it. I consider, therefore, tnat for this reason alone it is desirable to increase the waterway of the head-sluice. I propose to do this by extending the surface supply inlet which was constructed last year. This matter is referred to in more detail in paragraph 30 of this note.

26. On the Baroon side there is no question of the waterway of the head-sluice. It is amply large enough. It is the same size as the one on the Dehree side, and the discharge of the Eastern Main Canal is supposed to be 1,600 cubic feet. As a matter of fact I passed 1,925 down it in October 1895.

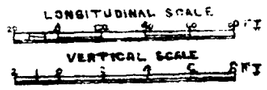
27. During the months of October, November and December the full discharge (1,600 cubic feet) was passed down the Eastern Main Canal, and the largest discharge possible down the Western Main, Arrah and Buxar Canals. This is undoubtedly clearing out silt, as the colour of the water shows, but it will not be possible, except in the head reaches where the canal is sectioned, to determine the quantities removed. I have great hopes, too, that this flushing will prevent the growth of weeds: some Rs. 4,500 is spent annually in removing these obstructions. Last year, in the Patna Canal system, where a flush was run in the cold-weather months, there was no expenditure on weed clearance, but I do not consider that it is, as yet, proved that this was due to the flush.

VI.—THE WORKING OF A "SCOURING FLEET" IN THE MAIN EASTERN CANAL.

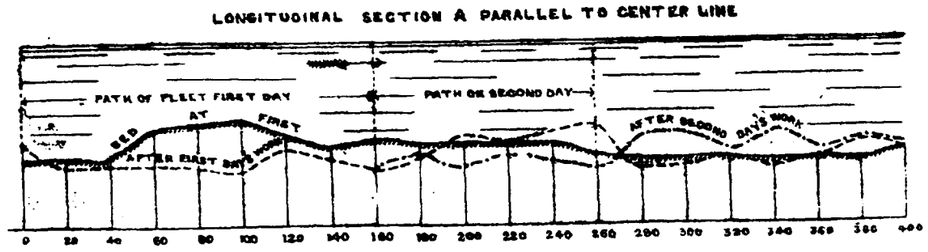
28. The 'scouring fleet' consisted of two mud punts fastened together with three shutters at the stern aggregating 40 feet in width and 9 feet in depth. These shutters are inclined at an angle to the surface of the water, so that the stream which is diverted by them impinges on the bed and stirs up the silt. The fleet is worked backwards and forwards from side to side of the canal by a capstan. It is similar to those used on the Sirhind Canal in the Punjab and the flushing barges used on the coast canal. The 'fleet' woked during the day in the earlier part of the silting season, but from the 24th of August it was worked day and night. As the sand in the bed of the canal is always moving by the action of the current, it is difficult to determine with any accuracy the amount of work the 'fleet' does. It certainly stirs up the sand and pushes a wave of sand in front of it as shown in the diagram on the opposite page displaying 48 hours' work of the fleet. This diagram was worked out with a good deal of care by Babu Bamachurn Mulick. The sections A, B, C, D, E, are taken along the bed of the canal 15 feet apart: they show the wave of sand clearly.

Calculations made from these diagrams show that in the first period of 24 hours the 'fleet' displaced 9,338 cubic feet of material in its path of 140 feet, but 6,300 cubic feet of this was immediately deposited below, leaving 3,038 cubic feet which had passed away entirely, as far as could be ascertained. In the second

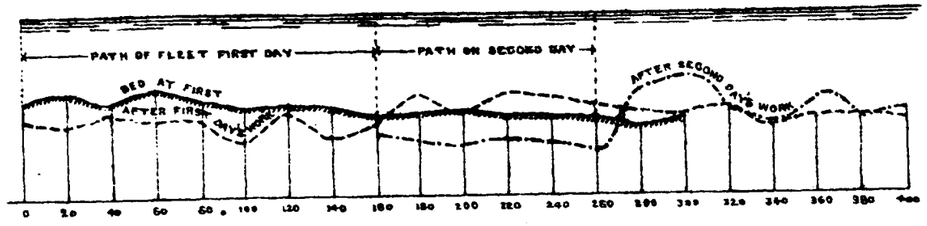
SECTIONS SHEWING ACTION OF SILT FLEET



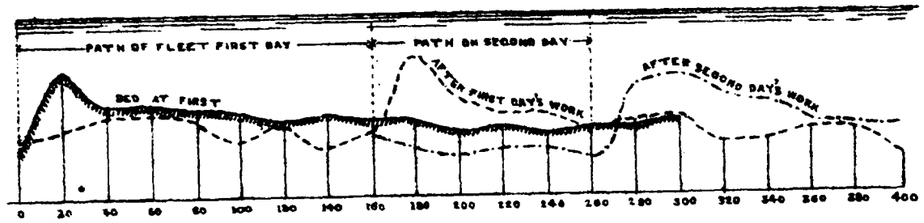
LONGITUDINAL SECTION A PARALLEL TO CENTER LINE



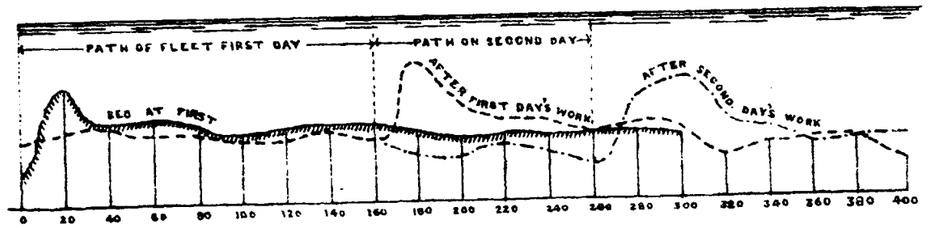
LONGITUDINAL SECTION B PARALLEL TO CENTER LINE



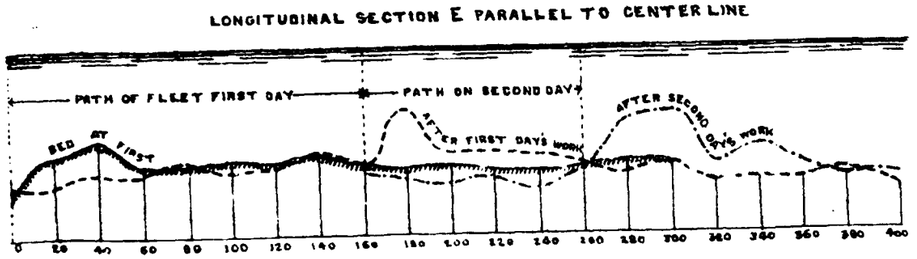
LONGITUDINAL SECTION C PARALLEL TO CENTER LINE



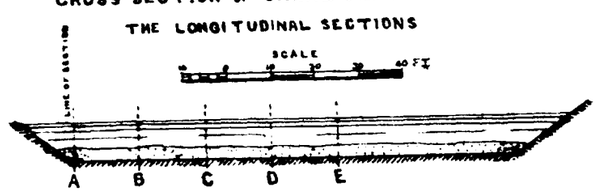
LONGITUDINAL SECTION D PARALLEL TO CENTER LINE



LONGITUDINAL SECTION E PARALLEL TO CENTER LINE



CROSS SECTION OF CANAL SHEWING POSITION OF THE LONGITUDINAL SECTIONS



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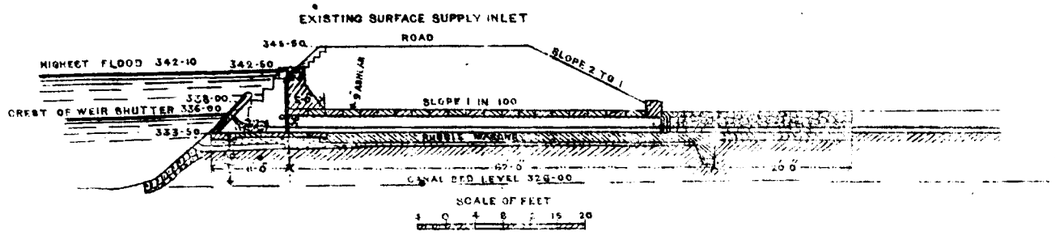
1897

period of 24 hours the fleet displaced 11,956 cubic feet from its path, but 9,380 cubic feet were immediately deposited, leaving 2,576 cubic feet which had been carried right away by the stream. The 'fleet' costs about one rupee to one rupee eight annas a day to work.

29. The efficiency of the fleet depends on the nature of the silt in which it works. If the sand is very muddy, I think there is no doubt that it washes all the mud out and that the mud passes away. If the material is pure sand of a size larger than the stream can carry, all the 'fleet' does is to press on the wave of sand before it. This year it has certainly effected something in the Eastern Main Canal, but I doubt if it has been of any great benefit.

VII.—THE CONSTRUCTION OF A SURFACE SUPPLY INLET AT DEHREE.

30. Before the last silting season a surface supply inlet was constructed at Dehree as shown in the following sketch. There were eight vents 4 feet wide:—



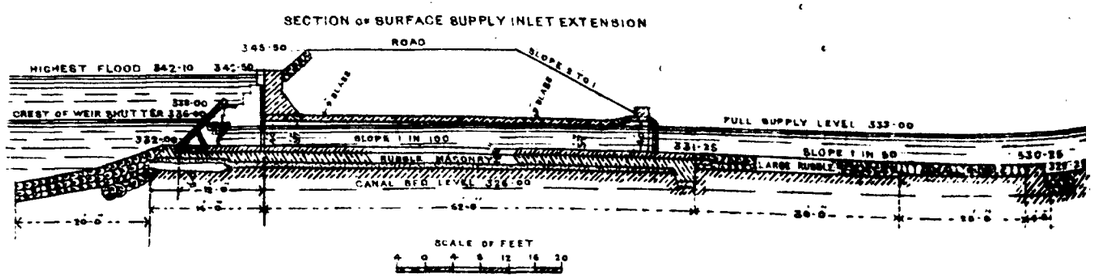
The following photograph was taken from a boat. It shows the river face of the inlet:—

The object of this inlet was to test experimentally the advantage of drawing water in a narrow film from the surface of the river. The floor of the inlet is at (333·50) 7·50 on the gauge, or 3 feet above the top of the lower shutters of the head-sluice. The kurries in the inlet were worked so that the depth of water flowing over them was never more than 2 feet. The channel from the inlet led the water into the lock channel (see sketch in paragraph 3 above), so that the silt brought in by the water was kept distinct from that carried in by the head-sluice. The levels at which the water was drawn through the head-sluice and inlet respectively are shown in Appendix No. 3.

31. The results obtained are detailed in Appendix No. 9. The lock channel has silted up to a certain extent with very soft mud into which a luggy can be thrust 2 or 3 feet. This fact shows the difference between the material which passes into the canal through the inlet and that which used to pass through the headsluice and be deposited at the head of the canal; that was coarse sand. The silt which has been deposited in the lock channel would not have been there at all had the inlet been large enough to keep up a sufficiently high velocity in the channel. The mud is now being scoured away to some extent as the canal level falls: it will probably be unnecessary to dredge the channel.

32. So far then the inlet has abundantly proved that by taking only the upper 2 feet of water all coarse sand can be excluded from the canal; but the season's working of the head-sluice has given the same results. Indeed, the facts set forth in Appendix No. 9 show that the water drawn through the head-sluice had less sand in it than that taken through the inlet—a fact which is probably due to the 'chur' which raised the river bed nearly up to the floor of the inlet.

I propose to extend the inlet with a lower floor as shown in the following sketch:—



I propose to do this partly because the results obtained this year in the Main Western Canal are, I consider, to some extent abnormally good on account of the 'chur,' and I desire to see a larger waterway at a high level; but my chief reason for wishing to extend the inlet is that which is set forth in paragraph 25 of this note, that is that the existing sluice is too small to admit the discharge which is at times required.

33. In the foregoing paragraphs I have explained the measures which were adopted and the reasons of them. I will now refer more specifically to the results obtained.

34. The results which have been obtained this year on the Baroon side (Eastern Main Canal) have not surprised me; those on the Dehree side (Western Main Canal) have. On the Baroon side the head-sluice, as it is now worked, has a maximum waterway of 528 square feet: the largest discharge which it is necessary to send down the canal is 1,600 cubic feet per second. So the full discharge can be obtained (with all kurries off) with a velocity of 3 feet a second. On the Dehree side the maximum waterway in the head-sluice now is 648 feet: the maximum discharge (allowing 200 for the surface-supply inlet) is 3,800, so that a velocity of 6 feet a second, or double that at Baroon, is necessary for the maximum discharge.

The water on the Baroon side was taken as a rule about 18 inches to 2 feet higher above the river-bed than that on the Dehree side. Volume of water passed in the Main Western Canal during the three months, July, August and September, was more than twice as gerat as that passed into the Main Eastern, and yet there was, at one time, some cause for anxiety on the Baroon side (a little dredging was

done), but on the Dehree side there was no such cause. The net accretion in each canal, during the silting months, (*i.e.*, up to end of September) is shown by this statement:—

Length.	Eastern Main Canal.	Western Main Canal.
1	2	3
	C. FT.	C. FT.
First quarter mile	114,045	99,924
Second do.	268,758	40,040
Third do.	77,220	— 60,060
Fourth do.	17,820	80,520
Total first mile ..	477,843	160,424
Total second mile ..	228,324	231,000

so that the accretion of the Baroon side was considerably greater than on the Dehree side, although, in addition to the facts already stated, the scouring 'fleet' was worked the whole time at Baroon, and not at all at Dehree. Samples taken at regular intervals along both canals showed clean sand at Baroon and dirty sand, or mud with little or no sand, at Dehree.

35. I think, then, that there is no doubt that more sand was taken into the Eastern Main than into the Western Main Canal by a given volume of water this year, and I have little doubt of the cause. The chur which has formed at Dehree above the inlet was the cause. This chur is shown in the sketch in paragraph 3 of this note: the top of it is about 334·00, that is, it is level with the crest of the weir. At ordinary levels, during the silting months, there is very little water over the chur, and consequently a small velocity. The water which supplies the canal mainly flows round the chur, and, as the first four under-sluices (and more if possible) were kept closed this year as much as could be, the water had a very small velocity as it approached the head-sluice. Consequently it carried no large sand and very little fine sand. At Baroon there was no such chur. This opinion obtains much confirmation from an observation made by Mr. Stawell, who gave me much help in these matters. He observed that the sand in the bed of the river immediately above the under-sluices which had been kept closed was finer—much finer—than that in front of the sluices which had been kept open. The water then which was drawn into the canal had no opportunity to pick up coarse sand from the bed, even if the velocity was sufficient to do so, as the coarse sand was not there.

36. The chur, then, if my opinions are correct, does us good service. But it is not likely to remain long where it is: a similar chur formed in 1878, and was carried away again; so, no doubt, this one will be. The conclusion I draw is that the good results obtained this year on the Dehree side must not be regarded as being certain to recur. No doubt the various measures which have been adopted to stop silt have done a great deal, but it is at least possible that the chur did nearly as much. It is partly for this reason that I propose to increase the waterway of the surface supply inlet at Dehree. If we could be certain that this year's results would recur annually, it would be unnecessary to increase the waterway on account of silt alone.

37. I have very little doubt that, if the surface supply inlet is enlarged and the various measures which have been adopted this year are perfected, it will be possible to stop all dredging and silt clearance at the heads of the two main canals.

38. The great advantage which will be gained by a solution of the silt problem on these canals will be the security that the canals will never be choked; but the financial advantages will not be small. The following statement is taken from pages 44 and 45 of the Superintending Engineer's Revenue Report of 1894–95,

It includes the silt clearance by hand and dredging on all parts of the canals (excluding drainage cuts):—

Period.	Cost of silt clearance.		Repairs to dredging plant.	Total cash expenditure.	Interest on capital cost of plant.	Grand Total.
	By hand.	By dredgers.				
1	2	3	4	5	6	7
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Average annual charge for five years ending March 1889 ..	30,936	62,826	13,575	1,07,337	19,609	1,26,946
Average annual charge for the five years ending March 1894.	36,648	62,925	14,087	1,13,660	19,609	1,33,269
Actual charge for the one year, 1894–95	36,410	40,264	11,630	88,304	24,099	1,12,403

The actual expenditure in 1895–96 is not, of course, accurately known, but it can be pretty closely estimated to be—

Estimate, 1895–96	Rs. 2,000	Rs. 14,000	Rs. 7,000	Rs. 23,000	Rs. 24,099	Rs. 47,099

This shows a cash saving of Rs. 90,000 on the average annual charge for the five years ending March 1894 and Rs. 84,000 on the corresponding figures of the previous quinquennial period. The saving is probably to some extent enhanced by the fact that there has been no closure of the Main Western Canal in 1895–96. The figures include the expenditure on silt clearance in distributaries which used to cost about Rs. 4,000 a year, but which was reduced in 1894–95 to about Rs. 1,000, and will, I hope, be kept down to that. Silt staunches a distributary and it is an absolute loss to take it out unless the obstruction interferes with the supply of water. I am always preaching "leave silt alone unless you can prove it is doing harm." It seems to have been the custom, which contractors were no doubt glad to perpetuate, to take out any silt that could be seen. In nine cases out of ten it is better left alone.

39. Appendices 10 and 11 give some detailed statistics of the quantities and cost of silt clearance in the Sone Canals.

40. The work which has been done this year with reference to this matter has not been small. I have to express my acknowledgments chiefly to Mr. Stawell, the Executive Engineer of the Dehree Workshop, for much trouble and care taken by him in the silt experiments and in all the arrangements for the regulation at Dehree; also to Babu Tarinee Churn Sircar and Babu Bamachurn Mulick, who have been in immediate charge of the regulation of the head works.

R. B. BUCKLEY,
Superintending Engineer, Sone Circle.

The 31st December 1895.

LIST OF APPENDICES.