The Ganges Canal.

A DISCUSSION,

REGARDING

THE PROJECTION AND PRESENT STATE

OF

THE GANGES CANAL,

AND THE

MEASURES REQUIRED TO MAKE IT RELIABLY USEFUL AND PROFITABLE.

BY

MAJOR-GENERAL SIR ARTHUR COTTON,

AND

COLONEL SIR PROBY T. CAUTLEY, K.C.B.

LONDON:
PRINTED FOR PRIVATE CIRCULATION.
1864.

Digitized by Google

CONTENTS.

Digitized by Google

386.54
C829

I.

Private Memorandum,

WRITTEN BY

MAJOR-GEN. SIR ARTHUR COTTON,

UPON THE GANGES CANAL,

FOR THE INFORMATION OF THE EAST INDIA IRRIGATION COMPANY.

THIS great work, even as it has been projected, would have paid a large *direct* interest, besides far greater benefits to the landowners and public generally, had it been carried out to completion, and it will do so still if completed. It has already saved tens of thousands of lives, and an amount of property probably exceeding its cost, during the late famine.

There are, however, the greatest *fundamental mistakes* in its projection, which have made a prodigious difference in the results. They are as follow :—

1st. The head of the canal is placed too high up, above a tract which has a very great and inconvenient fall, and in which there is a very heavy drainage from the Sub-Himalayas, across which the canal has to be carried.

2nd. The *whole* canal has been cut so as to carry the water *below* the level of the surface, entailing a vast unnecessary excavation, and keeping the water below the level at which it is required for irrigation.

3rd. The whole of the masonry works are of brick, while

JUL 25 '47 HERZBERG LIBRARY
AUG 6 '43

1039552

Digitized by Google

the most suitable stone for hydraulic works is procurable in the sub-Himalayas;—this is a most inexplicable mistake.

4th. The *whole* of the water is admitted at the head, so that some of it is *conveyed three hundred and fifty miles* to the land it irrigates, while it might have been obtained at a sufficient level at a distance of say 50 or 100 miles.

5th. There is no *permanent* dam across the river at the head of the canal, so as to *secure* the supply of water, but *temporary* works are thrown up after every monsoon, which are liable to be swept away, and have been swept away, at the very time when they are most wanted.

The first four of these fundamental mistakes have caused the cost of the works to be probably three times what they need to have been, consequently have increased the time of execution threefold; so that they might have been yielding 20 or 30 per cent., or much more, for the last ten years, instead of being to this day an unpaying project, with interest accumulating for ten years.

But besides these *fundamental* mistakes in the projection, there are the following *minor*, but still most important, ones:—

1st. All the weirs are made of a length corresponding with the full breadth of the canal, while they need not, and ought not, to have been more than one-third of that length, entailing a more than double expense in their construction, besides other destructive evils, which will be more fully explained.

2nd. These weirs are placed *in the direct line* of the canal, while the navigation line and the locks are placed *out of the direct line*, thus compelling *the whole of the traffic* to go round, instead of the irrigation water.

3rd. The whole canal has *too great a fall in its bed*, from

Digitized by Google

15 ins. to 12 ins. per mile, which, with a depth of 10 feet, which it was intended to have, gives a current of 2½ or 2¾ miles an hour, which is too much both for the bed and banks of the canal, and also for effective navigation.

4th. The canal has been terminated at Cawnpoor instead of being carried on 120 miles to Allahabad, where the Jumna and Ganges unite, and the river navigation begins to be effective throughout the year.

5th. The slope of the canal is continued to the end at Cawnpoor, so that to keep the navigation open there must be a large body of water constantly flowing to waste into the river.

6th. The bridges are so low as to prevent a fully-loaded boat passing under them.

7th. The towing-paths are not carried through the arches of the bridges, so that the line has to be thrown off at every bridge, that is, at every 3 miles.

8th. The lock channels have such sharp curves that boats of the length of the locks cannot pass through them.

9th. No arrangement has been made for the disposal of the silt.

10th. There are no *connecting navigation lines* between the different main branches, so that boats can only get *across* the tract by going all the way up to the point where the branch and the main line divide.

11th. The Solani Aqueduct is made of *the full breadth of the canal above,* and of *the full length of the breadth of the river below,* whereas it might have been made of *one-third of the breadth of the canal,* and its length of about *one-half of the breadth of the river,* reducing its cost to perhaps one-quarter or one-fifth of what it has been.

12th. The breadth of the canal at the lower end is much

Digitized by Google

too small for a large traffic, such as there would be if the navigation were in an effective state.

13th. The slopes of the sides of the canal are much too steep.

14th. There is no communication between the canal and the river at Cawnpoor; for though there are double locks the gates of the lower one were not in repair. I am credibly informed that, when they were in repair, boats were not allowed to pass backward and forward, but if they entered the canal were compelled to remain in it, because, as I was informed, they often injured the plastering on the lock walls.

I purpose now to enter more fully into the subjects of the different mistakes I have adverted to.

1st. *As to the position of the head of the canal.* In the reports I have seen there is no discussion at all on this point. In a paper of Colonel Baird Smith, on the late famine, he merely remarks that, the channel of the river below the steep country near Hurdwar is too deep for head-works for a canal.

In the first place, as the head of the canal from Hurdwar to Roorkee, 20 miles, which has so great a fall, and crosses all the heavy drainage of the Sub-Himalayas, has cost about $\frac{3}{4}$ of a million sterling, it is impossible that it could have been more expensive than that to have *thrown a weir across the Ganges below the confluence of the Solani, and cut the head of the canal from there.* But further, I was informed by an officer of the canal department, that he had taken the level from the Futtyghur branch of the canal to the neighbouring bed of the Ganges in two places, and found it 40 feet in each, while the fall of the country there is about 3 feet a mile; hence, if the water of the river were raised 10 feet by a weir, and the head of the canal cut from it with a

Digitized by Google

fall of half a foot a mile, gaining 2½ feet a mile upon the slope of the country, it would only require a cut of 12 miles in length to lead the water out upon the present level of the canal, which could not possibly be an expensive work; it could not certainly cost more than 1-10th of that of the present head of the canal above that point, while including also the permanent weir, which the present head of the channel has not.

The objections to this position for the weir (probably a little below the confluence of the Solani) would be—1st. That, it would be further from the quarries. But as no stone has been used in the present works, this does not affect the question so far as these works are concerned. The stone would certainly have had to be brought some considerable distance, but this, though it would have increased the expense, would not by any means have done so to the extent of the least making it a question *whether the weir could be built there or not.* But now, as the stone could be brought from Hurdwar by the present canal, with 3 or 4 miles of addition, to the very spot, the cost of carriage would be of very small account.—2nd. The country *above the point where the new head would meet the present canal* would be above the level of the water, and consequently could not be irrigated from this work. This is not of the least consequence; there are many millions of acres *below* the level of that point which are not irrigated, nor intended to be irrigated by the present works, and it cannot therefore be a matter of the least consequence that a few hundred acres *above that level* are not irrigated. There is no reason whatever for irrigating that particular *little patch of country about Roorkee,* rather than *the vast area of the Doab lower down*—and further, of course, now, that tract may *continue*

Digitized by Google

to be watered by the present canal. The fall between Hurdwar and Roorkee is about 60 feet, and is of no use whatever, so that going up to that point was only bringing into the canal a height of 60 feet, which had to be counteracted by weirs and locks at a great expense, without any object whatever, besides entailing, the enormous cost of passing the Solani and the other violent jungle streams which bring down enormous floods for a few hours at a time.

It must be observed that *the weirs on this part of the canal above Roorkee are in great danger.* Last year one of them was repaired, but was again injured, and it was necessary in consequence to close the head of the canal, and *put a stop to all irrigation for four months in the main irrigating season,* entirely losing the whole revenue for the Rubbee or winter crop. The receipts for the previous year had been 6 lacs, and in consequence of the extended distribution those for 1862-3 would have been, I believe, almost 10 lacs, whereas they will be, I suppose, less than those of last year. But the loss of property, in the crop, would have been enormous, perhaps 30 rupees an acre on 500,000 acres, or 150 lacs, besides the loss of seed and labour, had there not occurred most providentially a very unusual fall of rain, which gave even above an average crop. This mischief was solely owing to the weirs being built of brick, which can never be trusted for hydraulic works *with falls of water or high velocities.* Had they been properly-constructed works covered with stone, there would have been no such danger. It must be known also that this danger has occurred *with only seven feet* of water in the canal, whereas the works were calculated *to bear ten feet* of water, which has not yet been admitted. The quantity of water calculated upon was about 8,000 cubic feet per second, one million cubic yards per hour, while the quantity actually admitted is only about

Digitized by Google

5,000 cubic feet per second, or 620,000 cubic yards per hour. *And of this, in consequence of the want of distribution works, only one-fourth has ever been used, even during the famine, the remainder returning unused into the river.*

This great mistake of beginning the canals needlessly high up the river was very nearly made in the case of the Godavery. It was at first thought that they should commence at the point where the river escapes from the hills, but upon levelling the country it was found that nothing would be gained by this but the having to convey 1½ millions of cubic yards of water 25 miles for nothing—the gain of level by going 25 miles higher up giving no advantage worth mentioning; while if it was wished to water the small additional tract so commanded, it might be done by a separate work, without incurring the enormous expense of carrying 1½ millions of cubic yards all that additional distance. This change in the position of the head of the channel would have saved 70 lacs, and of course several years, besides all the loss and danger now experienced in the actual state of their head-works at this moment, which is such that, unless decisive measures are immediately adopted, the canal will continue useless, and the prejudice against irrigation works be prodigiously increased.

It is certain that *something must be done about these works;* first, those now in danger must be secured, and, secondly, the supply of water to the canal must be *secured by a permanent weir*. In the year of the famine, the temporary dam across the river had been constructed after the monsoon, as usual; when the river began to rise in the following monsoon, this dam was as usual carried away; but in consequence of the failure of the rains, the river did not continue to rise as it ought, and, consequently, at the very time when the canal water was most urgently called for, the proper

Digitized by Google

supply could not be thrown into it, as there was not enough water in the river to keep that in the canal at the required level, but at the same time there was too much to allow of the temporary dam being restored. Thus a work which has cost 2¼ millions is liable to be left without a sufficient supply of water, at the time of a failure of a monsoon, when the general need for the canal water occurs to prevent a famine, *for want of a permanent weir that would cost* 30,000*l.* *or* 40,000*l.* The canal, even with this insufficient supply of water, is of course still of incalculable value, though of nothing like what it ought to be. In the late famine it watered about 300,000 acres, and *produced* food for 1½ millions of people for a year, according to Colonel Baird Smith, besides being the means of conveying vast quantities of food from distant districts, neither of which would have been otherwise obtained; and, as many thousands died of starvation as it was, probably hundreds of thousands would have perished but for the canal, thus imperfectly supplied with water from the head, and only about one-fourth of that water being actually used for want of the distributing channels to convey it to the lands. Its use also for bringing food from a distance was only a small part of what it ought to have been had the defects of the navigation not existed, and had it extended to the confluence of the Jumna, at Allahabad, instead of stopping short at Cawnpoor.

But to return to the question of the head-works, which is, *What should now be done there?* I have stated that *the present weirs cannot stand the force of water to which they are exposed,* even with only 7 feet in the canal instead of 10 feet, the full supply; also that *a permanent weir must be built.* If the present head were still used for the admission of the *whole* supply of water, it seems to me that the only thing that can be done to meet the emergency is to build

Digitized by Google

new weirs on side cuts out of the line of the canal opposite to the present weirs, so that they may be completed without shutting the water out of the canal; and when completed the banks at the heads and outlets of the new cuts may be cut through, and earthern banks thrown across the main canal, so as to shut off the water from the present weirs. The new weirs, of course, to be constructed of stone.

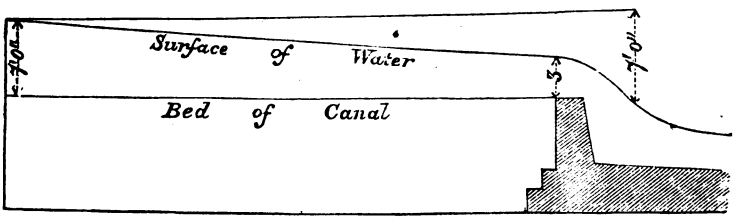
But *if the new permanent weir across the river is constructed, not at the present head, but below the confluence of the Solani, so as to admit the main supply from the river at that point*, only a small quantity might be admitted at the *present* head, so as to allow of only 2 or 3 feet flowing down that part, and so relieve the present insecure weirs; and this they would probably be able to bear, with the help of some trifling alterations. The object of admitting any water at all at the old head would be merely to keep up the navigation there, and to supply the small tract now watered above the level of the proposed new head. The traffic at this extreme part of the canal will, of course, not be very great so far as general traffic is concerned, but as affording the means of conveying the excellent stone of Hurdwar, and the timber of the Himalayan forests, both to the works all along the canal, and for the use of the public all the way to Allahabad, this part of the navigation will be of great importance.

If the depth of water is reduced from 7 to 3 feet, the current will be diminished from $2\frac{1}{2}$ to $1\frac{3}{4}$, which the bed and banks will bear, and the force of the water over the weirs will be greatly diminished.

It is necessary here, however, to point out another fact with respect to these weirs across the canal. I have stated that the length of them is the same as the full breadth of the canal, and consequently the depth of water passing over

Digitized by Google

their crest is less than that of the canal at a distance above the weirs. It is obvious that the velocity of the water over the weirs will be much greater than that in the canal, and consequently a depth, for instance, of 7 feet in the canal would not keep up a depth of, suppose, 3 feet over the weirs. Now, the bed of the canal is made with a slope of $1\frac{1}{4}$ feet a mile from the foot of one weir to the top of the next, so that the surface of the water will have an additional fall of 4 feet in the canal above, more than the bed; thus:—



so that, while the canal has nominally a slope of only $1\frac{1}{4}$ feet a mile, giving a current of $2\frac{1}{2}$ miles, the last mile or two above a weir has a slope, of the surface of the water, of perhaps 3 feet a mile, giving a current of 4 or 5 miles an hour—far above what was intended, and above what the bed and the banks can bear. The fact is, the weirs ought to have been made, so much shorter than the breadth of the canal, as to have kept the depth over their crest the same as that in the canal, so that the slope of the surface of the water would be the same as that of the bed of the canal, and the current would then have been kept at $2\frac{1}{2}$ miles an hour, as intended. The current above the weir has thus been so excessive that the sides of the canal were cut away to a dangerous extent, and to remedy it, the desperate measure, has been resorted to, of raising, by timber work, the height of the weirs, and thus *exposing those weak*

Digitized by Google

structures of brick to a force of water now much beyond what they were intended to bear.

It seems, therefore, almost certain that, *by making a new head to the canal below the confluence of the Solani*, far less expense will be incurred than *by correcting the works on the canal above Roorkee.* If these works, with the help of slight alterations, will bear a depth of water in the canal of 3 feet, instead of 7, as at present, the cost of cutting 12 or 15 miles to form a new head will be less than the substitution of stone weirs for the present brick ones. The weirs across the Ganges will, of course, be *nearly the same*, whether built at Hurdwar or below the Solani.

With respect to the second fundamental mistake, viz., *the cutting the canal so as to carry the whole body of the water below the surface of the ground.*—This was entirely owing to the medical officer appointed to investigate the subject of fever—which, *under certain circumstances*, had appeared in *irrigated* tracts—going out of his depth in attempting to instruct the Engineers how they were to execute the works. He had concluded that the fever was caused by the presence of the stagnant water, and he supposed that if the water was carried above the level of the ground it would percolate through the embankments, and keep the ground outside saturated. Not being an Engineer, he did not know that, the water would not find its way through the embankments in any quantity, nor that in that part of the country the upper 3 or 4 feet is *generally* of water-tight soil, *below which is the most open sand*, through which the water passes quite freely. Hence, in insisting upon the water being carried *below* the surface, he took effectual means to *produce the very evil he wished to prevent.* Had he merely insisted upon it that there should be no

Digitized by Google

land saturated with stagnant water, the Engineers would have known how to accomplish that. But further, the very object of the canal was, to irrigate the land without the necessity of raising the water by artificial means; to do this, and yet have the surface of the water below the level of the ground, was evidently an absolute contradiction. And hence the water is, of course, now let out of the main canal by the branch channels, so cut as to bring the water out above the ground, and thus the water is only *below the surface in the main canals,* while it is *above it in the branches.* The *real remedy against stagnant water* is simply a system of drains leading it off to lower levels; and this is essential to any effective system of irrigation. In consequence of the main canal having been cut so deep, the water is let through into the sand below, and the whole country is permeated by it, *so that the water everywhere stands some feet higher in the wells than it used to do, and the people are tempted to raise it by bullocks from them instead of purchasing it from the canal.*

In thus following these instructions instead of determinately protesting against them, the Engineers have been led into a monstrous expense and loss of time. *The excavation is certainly three times what it need to have been,* being about 4 yards by 50, whereas an excavation of one yard or a little more, just sufficient to form the embankments, was all that was required; and as the embankments could have been placed at any distance apart, without increasing the quantity of earth required to form them, a body of water much greater than is at present conveyed might have been provided for at one-third of the present cost. Thus, supposing the embankments required a section of 60 square yards each, to allow of a depth of water of 3 yards above the ground, and they had been placed 200 yards apart, the

Digitized by Google

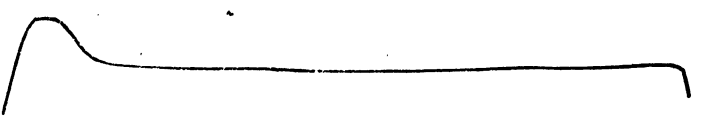
excavation would have been 120 square yards, and it would have provided for a stream 200 × 3½ yards, or 700 square yards, while the present excavation is about 4 × 50, or 200 square yards, and the stream of water 50 × 3⅓, or 170 square yards in the former, and the stream would have had a section of six times that of the excavation; while, as it is, *the section of excavation exceeds that of the water.* However, a far greater use may be made of the present excavation than has been made hitherto, *by simply allowing the water to stand in it above the level of the ground.* I have said that it was intended to allow 10 feet to flow down the canal, but hitherto only 7 feet has been admitted, in consequence of the works not being able to bear it with the present great slope of the bed, and the weak brick weirs. But the water might be allowed to stand at least 2 yards over the surface, or 6 yards deep, giving a section of water of about 60 yards by 6, or 360 square yards, instead of 50 by 2⅓, or 117, as at present; and if the current, by diminishing the slope of the bed, is lowered from 2¾ miles, as at present, to 1¾, just double the present quantity of water would be conveyed. The alterations that would be necessary for this, viz., the addition of some weirs, in order to diminish the slope, are absolutely necessary to make the navigation effective. *In this way alone, without any additional excavation, the canal may be made to irrigate twice what it is calculated to do, while only 7 feet of water are admitted.*

Other means will hereafter be mentioned by which a far greater extent of irrigation may be obtained without any additional excavation of the main canals.

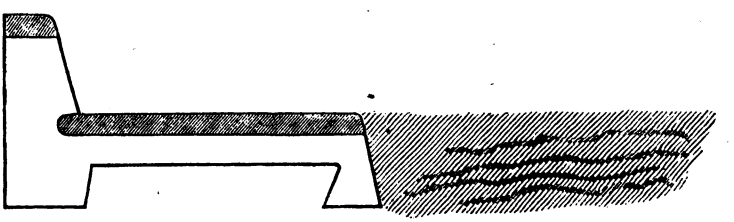
With respect to the third fundamental mistake—*that of constructing the works entirely of brick.*—There is nothing more inexplicable than this in the whole matter. I cannot

Digitized by Google

find a word of discussion on this point in the published reports on the project. I had always *supposed* that the only great objection to it was *the want of stone;* and I was astonished beyond measure to find the most unexceptional stone lying in the streets of Hurdwar, which I was informed had been brought only 6 miles, and many of the houses built of stone. What could have been the reason of rejecting this invaluable material, the very thing that was wanted for the works, I am still totally at a loss to conceive. In Madras we never think of trusting to brick for hydraulic works, however hard and expensive to cut the stone obtainable may be, nor however far we may have to bring it; and, in my opinion, nothing but the absolute impossibility of obtaining it within a practicable expense would justify an Engineer in building weirs and sluices without it. The present case is the strongest confirmation of this opinion. Nearly three times the quantity of masonry has been used in these weirs that would have been required had they been covered with stone, and yet they are now in a dangerous state, quite unequal to the force of water they are exposed to. The form of section is of this kind:—



Had they been covered with stone the section should have been thus:—



Digitized by Google

In the Locks also, all the passages are of brick only; they ought all to be lined with stone most carefully fitted. The side walls also being of brick, the most peremptory orders are given that they are not to be scratched by the boats, and monstrous fines are inflicted for any injury to the plastering. Of course this is wholly incompatible with free navigation. The works ought to be so constructed as to bear the kind of usage to which such works are exposed. I found sandstone of various degrees of hardness: *the soft* would probably do for the parts of the works *not exposed to the rush of water*, or to the chafing of boats and vessels; and the harder for the latter parts. I saw some of just the requisite degree of hardness; quite sufficiently hard to resist water, and at the same time not needlessly hard so as to involve an unnecessary expense in cutting. In Madras we have been often obliged to use *excessively hard granite*, at a very great cost, where much softer stone would have answered the purpose. Besides the stone to be obtained from the hills, the bed of the river is entirely filled with good-sized pebbles, which might be extensively used for rubble masonry, and for protecting the sides and bed of the canal, where wanted. Among these pebbles are also plenty which are of hydraulic limestone, so that I should report of this spot that scarcely any place could be found where hydraulic works could be constructed so securely and so economically. I may mention that the brick masonry in these works is of the very best quality; both materials and workmanship are as fine as any I ever saw, and from the published accounts of cost, it is evident that they have been most economically executed. The mistakes are in the projection, and the use of brick where stone was on the very spot, and of the precise quality required.

Digitized by Google

If quarries are now opened in the Sub-Himalayas, there would doubtless be in a short time a prodigious traffic in stone along the whole line of the canal.

Many of these minor mistakes have further greatly increased the cost of the works; some of them are the causes of *the present dangerous state of some of the weirs and bridges,* and some of them almost destroy the canal as a line of navigation, so that the traffic on it in goods is now only 1-50th of what it ought to be, and it is hardly used for passengers at all, whereas if the navigation were effective, steamers of all speeds would be carrying passengers to the extent of several thousands a day; probably starting from either end of the canal every two or three hours, and plying night and day.

From the mere mention of these defects of projection, it cannot but be understood how it is that this work, in a tract of country with such prodigious natural advantages, has been so unproductive for seventeen years from its commencement, independently of the question of the distributive channels not having been yet completed.

The money that has been expended is probably three or four times what would have been sufficient both for the irrigation of two millions of acres, and to have formed the most effective line of navigation in the world, with a prodigious traffic both in goods and passengers at any required speed, and at a charge so low as fully to answer the demands of the country.

With respect to the fourth mistake, viz., *that the water is* all *admitted at the head of the canal, so that* some *of it is conveyed three hundred and fifty miles to the lands it waters at a monstrous cost.*—Supposing the land in the centre of the Delta is 50 feet above the bed of the river nearest to it, and that the fall of the country is 1½ feet a mile in a certain part (the actual fall is about 3 feet a mile near

Digitized by Google

Roorkee, diminishing to about a foot at Allahabad), it is evident that, if the water is first raised 15 feet by a weir across the river, and then carried by a canal with a fall of ¼ foot a mile, gaining 1¼ feet per mile upon the river, such a canal would only be carried 28 miles before it would have attained to the level of the land in the centre of the Doab, where it would command the whole tract, and might afterwards be carried along the water-shed; thus:—

	Feet.
Total difference of level between river and land . .	50
Height gained by weir	15
	35
Height gained by canal having a less slope than the land by 1¼ feet per mile, 28 miles at 1¼	35

In this case, therefore, instead of bringing the water, suppose 250 miles from Hurdwar to 100 miles above Cawnpoor, it would only have been conveyed 28 miles, and there would have been a saving of 225 miles of canal against the construction of a weir. The cost of the latter might be 5 lacs, and that of an excavation of, suppose, 50 square yards of section, say at 1½ annas per cubic yard, or 9000 rupees a mile, would be, for 225 miles, 20 lacs. But the difference of cost would only be a part of the advantage; it would provide for a large additional supply of water beyond what could be obtained from the present head, for it would secure the water draining out of the sands of the river in those 225 miles, besides any flowing into it from the small affluents that enter the river in that space. The same might be done with the Jumna, and thus at a small cost three or four times the land might be irrigated that is at present provided for. Probably one or two such additional heads from each of the rivers Ganges and Jumna might be cut

Digitized by Google

with advantage. It is to be observed that, the whole area of the Doab, all available for irrigation, is about 10 million acres, of which, say, about half a million acres have yet been supplied, and the present arrangements would only provide for 1½ million acres, even if the full supply of 10 feet depth were admitted into the canal, while the two rivers would probably supply 4 or 5 million acres, even when at their lowest and of course the canals should be cut so as to allow of a much greater quantity than the lowest supply being conveyed by them.

There remains also *the storing of water* to be considered. The information I obtained as to sites for large tanks at the foot of the Himalayas was not very favourable; but still I have no doubt that large quantities of water could be stored there at a practicable cost, though not so cheaply as in most parts of India.

I have already spoken of the necessity for *a permanent weir at the head of the canal, and of the unaccountable mistake of leaving a work that has cost 2¼ millions imperfectly and uncertainly supplied with water for want of an expenditure of* 30,000*l.* *or* 40,000*l.* There seems to be now something like a real impression that such a work must now be executed, but it is still put off, apparently under the strangest fancy that such a work is one of most serious difficulty, though *it is nothing to the works of the kind that have been executed in Madras* in many places, both by natives and Europeans. The quantity of water to be discharged over it in extreme floods is about *twenty-five million* cubic yards per hour, while the quantity which has to be provided for in the Godavery is *two hundred millions,* and in the Kistnah about *one hundred and sixty millions,* and both these works have been executed without any serious difficulty. The

Digitized by Google

officers at the head of the Public Works Department of India seem to be afraid of the work themselves, and unwilling to send for an experienced Madras officer to do it for them.

In the meantime, *what with the uncertainty of the supply, and the dangerous state of some of the weirs and other works,* this most important work is in the most imminent danger of becoming a failure, and a terrible obstacle to similar works. One season has been already entirely lost from the necessity of shutting the water out of the canal, and it can only be kept open this year with very great anxiety lest some of the weirs should fail entirely. *Not a moment should be lost in taking the works in hand with decision that are necessary to put the project in a safe and effective state.*

With respect to the minor mistakes I have mentioned :—

1st. *The weirs across the canal being made of a length corresponding to the breadth of the canal;* I have already shown the evils arising from this; besides that they have cost more than double what they would have done had they been made of the proper length.

2nd. *The placing the weirs in the direct line of the canal, and cutting channels with locks in them on one side of the main canal for the navigation;* There is no reason for this; *the navigation* was the thing to be cared for; it was a matter of no consequence that *the water* should be led round by a circuitous course. The boats now have to *get out of the current which leads direct to the weirs, and to turn into the side channel,* and of course not without danger. Some boats have thus been carried over the falls, and several lives have been lost. This should now be corrected, at least below Roorkee, by making new weirs out of the line of the canal. The present dangerous state of the weirs at any rate makes this *imperative,* and it is only by building

Digitized by Google

them out of the main line that the canal can be kept in use while they are under construction.

3rd. *The great fall in the bed of the canal,* $1\frac{1}{4}$ *to* 1 *foot per mile, which, with a depth of* 10 *feet, would give a current of* $2\frac{3}{4}$ *or* 3 *miles an hour, which is too much both for the bed and sides of the canal, and for the navigation.*—The sides of the canal have in several places been cut by the current, and the bed, especially at the bridges, dangerously deepened. It is absolutely necessary to diminish the slope by building additional weirs; and as there is nothing to prevent a much greater depth than 10 feet being admitted into the canal, and it is clear waste to admit into it, less than it can carry, the slope should be reduced to a very moderate rate. If 18 feet of water is admitted, which I believe the banks will abundantly allow of in a great part of the length, the slope should not exceed 3 inches per mile, which would give a current of about $1\frac{3}{4}$ miles, or 3000 yards per hour, and I think more than this cannot be allowed with safety to the sides, and without serious inconvenience to the traffic. In fact, I am of opinion that that current is the outside of what can be allowed, so as to make the navigation perfectly effective.

There remains the question of entirely correcting the level of the bed by cutting and filling in from weir to weir. This is not, perhaps, absolutely necessary, but it would not be very expensive. For instance, suppose in the lower part, where the slope of the country and of the bed is about 1 foot, and it would have to be reduced by 9 inches, it would require that weirs 12 feet high should be placed at every 16 miles; or if, as there would be less depth of water in this part, a slope of 6 inches were allowed, they would be required at every 24 miles.

Digitized by Google

It seems certain that the greater traffic will be down stream, and in such a case there is a decided advantage in having a certain current. In the upper part, at all events, the main traffic will be down; it will consist there chiefly of timber, firewood, and stone; the grain and other produce will of course increase from the upper to the lower end, and at the latter it will certainly be enormous. The up-traffic will indeed be very great at the lower end, in salt, coal, and rice, and this will diminish towards the upper end. The other traffic will of course be small compared with these items. The passenger traffic will be equal up and down, but of course regularly increasing towards the lower end. It must, however, be remembered, that when this navigation is connected with lateral lines, as in Oude, &c., many more and unexpected items of transit will be brought upon the line which cannot now be estimated. As the passenger traffic will probably be chiefly by steam, with speeds of 5 miles and upwards, the current will not so much affect that. I am inclined to think that it will be well to give one side of these canals a very long slope, 3 or 4 to 1, which will allow of the up-traffic getting almost entirely out of the current. Thus, a boat drawing 4 feet would be in a current of only half of that of the centre of the stream, or about three-quarters of a mile per hour. The additional expense of this would not be very great, and I think it would be a great benefit to the navigation.

Of course, if a great depth of water is allowed in the canal, there must be a proportionately reduced slope of the bed, the depth of water and the fall per mile equally affecting the current; that is, a depth of 18 feet, with a fall per mile of $\frac{1}{4}$ foot, and a depth of 9 feet with a fall of $\frac{1}{2}$ foot, would each give a current of about 3000 yards, or $1\frac{3}{4}$ miles in the

Digitized by Google

middle. The object in proposing so great a depth as the former is, merely to take advantage of the enormous excavation which has been made; it would certainly entail a greater number of weirs in reducing the slope to ¼ foot, the cost of which (and the more frequent interruptions from locks) must be set against the gain of additional water. Had the original mistake not been committed, of course the proper plan would have been, to make the embankments further apart, and then to have a less depth of water. Probably 6 feet would be an ample depth for navigation, and with that a slope of ¾ foot might have been allowed, which would have made a difference, compared with ¼ foot, of 240 feet between Hurdwar and Allahabad (480 miles at ½ foot), or of 24 locks, with 10 feet lift, one in every 20 miles.

4th. *The termination of the canal at Cawnpoor, instead of its being carried on* 120 *miles to Allahabad.*—This is a most serious mistake as respects the navigation, even if the irrigation were not carried below the first place. There is not one single obstacle of the smallest kind along this whole line; the rails are laid throughout almost on the surface of the ground, and very nearly in a straight line; the excavation, therefore, for a canal would be of the most insignificant kind. If it were made on a dead level, the fall being about a foot a mile, there would be 10 locks of 12 feet lift each, or one every twelve miles; the least excavation for a canal 40 yards broad and 9 feet deep would be about 60 square yards, to make two embankments 2½ yards high, the excavation being 1½ feet deep, and the greatest excavation would be just below a lock 40 × 5, or 200 square yards, and the average about 140 square yards, which at 1½ annas per cubic yard would give 24,000 rupees per mile, besides

Digitized by Google

locks and bridges; the former would cost about 30,000 rupees each, or 2500 rupees a mile. But the cost might be greatly reduced, by making the locks more frequent, with a smaller lift, as the excavation would then be greatly reduced, and it must be remembered that the interruption from locks is very insignificant if they are made with ample water passages so as to fill or empty in one minute. If the locks had a lift of only 6 feet instead of 12, the greatest excavation would be only 160 square yards, and the average about 110, or the cost 18,000 rupees a mile. This provides for a very large canal, 40 yards broad, and also supposes that no irrigation is provided for. But it would, no doubt, be better to irrigate from this part of the canal, as the giving the water a current would not increase the cost. Small weirs would be required, but fewer locks.

With this continuation of the canal, thus conveying the traffic into the Ganges at the confluence of the Jumna, the value of the upper canal for navigation would be prodigiously increased, and the returns from tolls accordingly. If the extension cost 25,000 rupees a mile in all, a net toll of ½ pice per ton, and per head, would require a traffic of half a million tons, and half a million passengers, to give a return of 10 per cent. on navigation alone, and I feel confident that the traffic would soon equal that. If the Soane or the Oude projects are carried out, of course this line would be connected with them by aqueducts across the Ganges and Jumna, and a vast impulse would thus be given to the traffic on the Ganges canal.

5th. *The continuation of the slope of the canal quite to the end at Cawnpoor.*—The consequence of this has been a continual cry that water could not be spared for navigation. *No water is required for navigation, excepting for lockage,*

Digitized by Google

which is insignificant, and for evaporation, which on a canal 40 yards broad is about an average of 20* cubic yards per hour per mile, a matter of no consequence. *The only thing that is required in combining navigation with irrigation is to reduce the line of the canal, below where the irrigation ceases, to levels by locks.* If the last 30 or 40 miles above Cawnpoor had been thus reduced to levels by three or four locks, *no flowing water would have been required.*

6th. *The low bridges.*—Only 7 or 8 feet of headway has been allowed, a most serious obstacle to navigation, especially to steamers. The remedy for this is to cut side channels at all the present bridges with higher arches, or rather, perhaps, with girders. About 10,000 rupees each would probably provide for girder bridges with a span of 45 feet, allowing of two boats passing each other under them, with the excavation. The channels should lead off from the present canal at extremely easy slopes, so as to offer no inconvenience to the navigation. Supposing there are 120 bridges on the canal, this correction would cost about 12 lacs. It would not interrupt the use of the canal, and with girders the whole could be done in a few months. *This is absolutely necessary. The present state of the bridges is almost destructive of navigation, especially of steamer-passenger traffic.*

7th. *The towing-paths not being carried under the bridges.*—This will be corrected by the side bridges above proposed.

8th. *The sharp curves in the lock channels.*—This must be corrected in the present lock channels by lengthening them, which can be done at no great expense. When additional weirs are constructed, as they will be placed out of the line of the main canal, the new locks should be placed close to

* By some mistake in the original Report this was stated to be 2 cubic yards instead of 20.

Digitized by Google

the side of the latter, so that they may be built without closing the canal, but with a very slight deviation from the straight line of the canal.

9th. *The disposal of the silt.*—I think this should be *expressly provided for in all such works in future.* If water flowing at 5 or 6 miles an hour be admitted into a canal, and its current reduced to 2 or 3, the greater part of the suspended silt is of course rapidly deposited, and most of this is simply barren sand, which is very injurious to the land.

10th. *The want of cross lines of navigation to connect the different branches of the canal.*—This is a great defect, and it can be remedied at a small cost. The whole breadth of the Doab is small, and level lines could be selected to lead from one branch to another without any difficulty. It is evident that if to get from one side of the Doab to another —suppose 40 miles—they have to go 250 miles up one branch, and 200 down another, it is a most unnecessary evil. A few cross lines can be cut for a trifle so as completely to remedy this.

11th. *The Solani Aqueduct.*—This cannot now be corrected, as the money has been spent, but the consideration of the subject is of great importance in its bearing on the cost of irrigation works. The dimensions of the *earthen canal* were decided upon the basis of the current that earth could bear; it was allowed in this case to be 3 miles an hour. The dimensions of the *masonry aqueduct* were then made *exactly the same.* Why? In passing water through *masonry* we are not restricted to 3 miles an hour. The water passes through the lock passages at, perhaps, 10 or 15 miles an hour, or more. It is evident that the water might have been sent through the aqueduct at three or four times the rate that it passes along the earthen canal; and hence that a work of one-third or one-fourth the width of

Digitized by Google

the canal would have been sufficient. In Tanjore we never think of making *masonry aqueducts* of the same dimensions as *the channels that lead to them.* The Solani Aqueduct is 250 yards long, so that a fall through it of $1\frac{3}{4}$ feet, equal to 12 feet a mile, would have given a velocity of 9 miles an hour, or three times that of the canal; and have consequently reduced the breadth of the work to one-third, and consequently the cost to little more than one-third: a saving of, I believe, 9 lacs. The navigation, of course, is small at this extreme point of the canal, but it might have been provided for, either by heaving the boats through by means of crabs worked by men or cattle, as is done in the rapids of the Wye, and other rivers in England, or by making a separate chamber of the breadth of the locks, 16 feet, with gates to it. Even with this latter arrangement, the breadth of the aqueduct need not have been above 25 yards instead of 66; but probably the first plan would have answered the purpose, making it 6 yards narrower. In this way about 100,000*l.* might have been saved in this work. Again, in the same way, the water of the stream which it crosses, passes through it at a moderate velocity. But it would have been much cheaper to have strengthened it by an apron, &c., so as to have allowed of the water passing through it at, perhaps, double that velocity. In the Gunnarum Aqueduct in the Godavery Delta, the water of the river rises 5 feet over the crowns of the arches, and is discharged through it at a great velocity, the bed of the river being secured by rubble masonry and loose stone. In this way the Solani Aqueduct might have been made, perhaps, half the length it is, which, combined with one-third of the breadth, would have reduced the cost to about one-fifth of what it was, or 3 lacs, instead of 15, and have proportionately reduced the time of construction. *Now, whether an*

Digitized by Google

irrigation work is executed for 15 *lacs or* 3, *and whether it takes* 1 *year or* 5 *years to construct, make the difference of whether it yields* 25 *per cent. from the first year, or* 5 *per cent. after* 5 *years. It is evident that upon such things as these depends whether such works are an immense success or a partial or a complete failure.*

In building a bridge, an aqueduct, or a weir, the simple question is, how can a certain quantity of water be passed through or over at the least cost, viz., whether by a work of suppose a certain length, or a stronger one of suppose half that length. This is the point. Now in the case of the Kistnah Annicut, we have proof that we can discharge an enormous quantity of water *over a short weir*, about 200 million cubic yards per hour over one of 1100 yards, or 180,000 cubic yards per yard of length, and in the Gunnarum aqueduct we have a proof at how high a velocity water may be discharged *through a bridge* or aqueduct with safety.

12th. *The narrowness of the canal near Cawnpoor.*—This is out of all proportion to the traffic that there would be if the navigation were in an effective state. I am inclined to think that none of the main canals situated like this, in the heart of the valley of the Ganges, ought to be less than 30 yards in breadth, to allow of the free passage of fast steamers, and very numerous cargo-boats. They might, of course, be narrower as the distance from Calcutta increased. It would, perhaps, not be necessary to increase the breadth of this part of the canal by excavation, but merely by raising the locks and weirs so as to fill the present excavation to a greater depth, as the water at present stands many feet below the top of the embankments.

13th. *The steepness of the slopes of the sides of the canal.*—This can be easily corrected. If the canal is filled much

Digitized by Google

above its present level, the earth might be merely thrown down into the channel, but even if it had to be carried over to the back of the embankments, it would not be very expensive. At present there is a continual cry against a ripple on the banks, and a senseless denunciation of steamers on a canal; *if a canal is not made to bear this kind of thing, it is utterly inefficient.* An effective navigation, whether for goods or passengers, ought of course to be quite able to bear a ripple on the banks. For this the banks should have a good slope, and, if necessary, for a yard above and a yard below the surface of the water, the slope should be covered with loose stones, which can be done at a trifling cost. Suppose, for instance, 2 yards' breadth on each side, with a thickness of 1 foot, this would require 2400 cubic yards, or 3000 tons per mile, which might cost on the Ganges canal, if carried on an average 200 miles, 3000 rupees a mile; but I do not think this would be necessary unless the banks were of mere sand. In a canal of 30 yards broad and upwards, it is evident that it would be a matter of very little consequence if the slope of the sides near the water's edge were reduced to a slope of 5 or 6 to 1 by the ripple. *It is only in the small canals in England, where there is not a foot to spare, and which were not made to bear the slightest ripple, that this is a serious matter.*

14th. Incredible as it may appear, after constructing pairs of locks to connect the canal with the river at Cawnpoor, as if to provide for a vast traffic, the actual passage of boats from one to the other has been systematically obstructed, first by forbidding it, then by heavy fines for slight injury to the plastering, and lately by allowing the lock gates to get out of repair, so that the boats could not pass through. From first to last there seems to have been the strangest misapprehension of the importance of the

Digitized by Google

line of navigation, notwithstanding that a great expense has been incurred in locks. Lord Ellenborough indeed wrote a minute dwelling upon the importance of the navigation, but I have never been able to obtain a sight of it; it was written about . Of course every possible facility should be given for boats going from the canal into the river, or the contrary. Their not being allowed to do so probably at once stops five-sixths of the traffic. How so great an absurdity as the allowing the slightest obstacle to this to remain could have been permitted, is inexplicable.*

What I consider, therefore, is required to bring this most important work to completion, and to make it thoroughly effective, both for irrigation and navigation, as

---

* "I have spoken of the flowing of streams to the sea, as a partial image of the action of wealth. The popular economist thinks himself wise in having discovered that wealth, or the forms of property in general, must go where they are required; that where demand is, supply must follow. He further declares that this course of demand and supply cannot be forbidden by human laws. Precisely in the same sense, and with the same certainty, the waters of the world go where they are required—where the land falls the water flows. The course neither of clouds nor rivers can be forbidden by human will. But the disposition and administration of them can be altered by human forethought. Whether the stream shall be a curse or a blessing depends upon man's labour and administering intelligence. For centuries after centuries, great districts of the world, rich in soil, and favoured in climate, have lain desert under the rage of their own rivers—not only desert but plague-struck. The stream which, rightly directed, would have flowed in soft irrigation from field to field, would have purified the air, given food to man and beast, and carried their burdens for them on its bosom, now overwhelms the plain, and poisons the wind—its breath pestilence, and its work famine. In like manner, the wealth goes 'where it is required;' no human laws can withstand its flow. They can only guide it; but this the leading trench and guiding mound can do so thoroughly that it shall become water of life, the riches of the land of wisdom;† or, on the contrary, by leaving it to its own lawless flow, they may make it what it has too often been, 'the last and deadliest of national plagues, water of Marah, the water which feeds the roots of all evil.'"—RUSKIN.

† Length of days in her right hand, in her left riches and honour.—PROVERBS.

Digitized by Google

well as to obtain from it ample direct returns in money, is as follows:—

1st.—*To form a new head with a permanent weir below the confluence of the Solani,* through which the main supply of the canal would be received, leaving only a small quantity to be admitted by the present head, just enough to keep up the navigation to Hurdwar, and no more than the present works in that part of its course will bear.

2nd.—*To make such small alterations to the weirs, &c. there, as may be necessary to make them quite secure under the moderate force to which they will then be exposed.* Perhaps about 3 feet of water will be sufficient to allow to flow down that part of the canal, giving a current of about $1\frac{3}{4}$ miles.

3rd.—*To construct new weirs, below the new head, of stone, and out of the main line of the canal, instead of the present brick ones.*

4th.—*To add such additional weirs with locks as shall reduce the bed to a slope of from one quarter to one-half foot per mile,* so as to keep the current within $1\frac{3}{4}$ miles, and at the same time allow of the canal being filled as high as the banks will admit, so as to make full use of the present excavation.

5th.—*To increase the slopes of the banks* so that they shall not be liable to injury from ripple, and at the same time allow of boats, when ascending, to keep in shallow water, and avoid the strength of the current.

6th.—*To form a large basin near the heads of the canal,* through which the water will flow at not more than 1 mile an hour, for a mile or two, and thus deposit all its heavy silt, which may be removed by dredges constantly at work there without interrupting either irrigation or navigation.

7th.—*To construct new bridges* of one span of about 40 feet, as a continuation of each of the present bridges, just

Digitized by Google

out of the line of the present canal, of sufficient height to admit of free navigation, with a headway of 12 or 15 feet.

8th.—*To correct the present sharp curves in the lock channels.*

9th.—*To put the connection with the river at Cawnpoor in perfect order.*

10th.—*To extend the canal to Allahabad,* both for irrigation and navigation, both locking down into the river there also, and carrying it over the Jumna and Ganges by aqueducts to connect it with canals if constructed beyond those rivers.

11th.—*To form additional heads, with permanent weirs,* both in the Jumna and Ganges, 200 or 300 miles below the Solani, so as to admit additional water into the lower parts of the canal. The weir near the Solani will afford a larger supply than one in Hurdwar would in the lowest season, because additional water drains out of the sands in the intermediate bed of the river, and again a great additional supply will be obtained by weirs 200 or 300 miles lower down. But I would by no means restrict the supply in the canal to the lowest quantity in the river; there is plenty of time to secure a crop between the conclusion of the monsoon and the time of the lowest supply, which is in March, so that a much larger area may be watered than the lowest supply would provide for. The quantity as yet admitted has been only about 700,000 cubic yards per hour; the quantity in the river at the lowest below the Solani is more than a million, and probably half a million more may be admitted with advantage when there is so much in the river, and about a million more may be probably obtained from each of the lower weirs, making in all 4½ millions, or six times as much as has yet been admitted, and about

Digitized by Google

twenty-five times as much as has yet been used; and as 300,000 acres have been already irrigated, this would provide for 7½ millions of acres, the total area of the Doab being 10 million acres, of which about 150,000 acres are already watered by the Eastern Jumna Canal.

12th.—*The country at the foot of the Himalayas should be examined for sites for tanks, to provide a further additional supply of water in the cold season.* From such information as I could obtain, I conclude that that tract is not very favourable for this purpose, but still I think it will be found that water can be stored there at a practicable expense. If an acre can be watered for one crop by 1,500 cubic yards of water, and the water rate for a single crop is 1 rupee, it is evident that water stored at a cost of 1 rupee for 300 cubic yards will yield a return of 20 per cent., as no other expenses will be incurred in making use of it, excepting a very little for the small branch channels of distribution, all the other channels being supposed to be made of a capacity to convey a larger body of water than the river supplies when at its lowest. The above cost would be 3,300 rupees per million cubic yards, whereas we estimate that in favourable sites water may be stored at 500 rupees per million, and lower, so that there is abundance of margin in the above cost, and thus arrangement may be made for a vast extension of irrigation, and the canals ought to be made of great capacity to provide for the time when abundance of water may be stored.

13th.—*To cut cross lines of canal connecting the different branches at several points;* and especially to cut lines which shall bring the traffic from the various parts of the Doab as direct as possible to all the great cities, Agra, Delhi, &c. *The navigation of this tract will be very imperfect without these.*

Digitized by Google

14th.—*To cut long canal basins, skirting the cities of Cawnpoor, Allahabad, &c.*, so as to allow of goods and passengers being landed opposite to all points of them, instead of having only one square basin which will oblige the goods, &c., to be carried a long way through the streets.

15th.—*To cut the distributing and drainage channels for the extended irrigation.*

The following would then be *a rough estimate* of thus completing the project:—

New head and weirs near the Solani	£100,000
Correcting the present works *above* that point	20,000
New stone weirs on the canal *below*, instead of the present ones	5,000
Additional weirs and locks to diminish the slope of the canal to Cawnpoor	100,000
Sloping the banks of the whole canal, 700 miles at 300*l.*	210,000
Silt basins near the heads of the canal	5,000
New bridges with more headway; 150 at 8000 rupees each	120,000
Correcting the present lock channels	5,000
Alterations at Cawnpoor	10,000
Extension to Allahabad; 120 miles at 2,500*l.* a mile	300,000
Additional heads, with weirs on the Ganges and Jumna, 200 or 300 miles below the Solani	200,000
Storing water for 2 million acres, at 1,000 cubic yards per acre; 2,000 million cubic yards at 200*l.*	400,000
200 miles of cross canals at 1,000*l.*	200,000
Distributing and draining channels for 7 million acres at 1½ rupees an acre	1,050,000
Additional capital required	£2,725,000
Add already expended	2,300,000
Total cost	£5,025,000

Or for 6½ millions of acres, 15*s.* per acre.

This would probably include, at least, 2000 miles of first-class navigation.

Digitized by Google

II.

An EXTRACT *containing so much of a Lecture delivered by* MAJOR-GEN. SIR A. COTTON, *at the Calcutta Chamber of Commerce, on the 7th, May,* 1863, *as related to the Ganges Canal—referred to in the Reply of* COLONEL SIR P. T. CAUTLEY, K.C.B. *printed herewith.*

But when I proposed this subject (the extension of Irrigation Works in India) to Mr. Laing, he objected to *the small returns from the Ganges Canal.* As this is continually said, I must show the state of this case:—The expenditure up to this time has been about 2,250,000*l.*, including interest, the receipts of last year about 60,000*l.*, or 2¾ per cent. *gross.* The first plain and simple answer to Mr. Laing's objection is, that the project has not yet been carried to completion. The Canal is made of a capacity to carry water for about a million cubic yards per hour, sufficient for about one and a half million acres; it has as yet only watered 300,000. The distribution channels have not been completed. During the last year, indeed, great progress has been made with them, several hundred miles having been cut, and a great deal more water may be distributed this year. But even during the famine not one-fourth of the water entering the channel could be applied to the land; and when I was at Cawnpoor about 100,000 cubic yards per hour, sufficient for, perhaps, 150,000 acres, after being brought at a great expense 350 miles, was returning unused into the river at the end of only one of the branches of the canal. Thus, after spending 1½ millions on the main

Digitized by Google

works, many years have been lost in cutting the distributing channels. This is the main point in the question of the returns from this great work. It must never, however, for a moment be forgotten, that, in fact, *this work has repaid its cost over and over again by the incalculable benefits it conferred in the famine,* both by the food it produced and by that which it conveyed. It seems certain that, but for it, hundreds of thousands must have perished. Colonel Baird Smith reckons that it provided food for nearly one and a half millions of people for a year. It must also be remembered that it must even now be yielding a very large percentage in all, though only a small portion of it is realized directly by the government, the principal part going to the landowners. Nothing can be more evident than that any amount of money may be wasted upon the best planned projects, by only executing the heavy works and then making no use of them. *There must be something in a system producing such results, that ought to be, and can be, corrected.*

But I think I may take this opportunity of giving some further account of this work, the Ganges Canal, as it turns directly upon my main point,—the urging irrigation and navigation in the valley of the Ganges. There has been undoubtedly a far greater expenditure upon it than there needed to have been. One grand mistake was the excavating the whole section of the water-way, so as to carry all the water *below* the surface. This was entirely owing to the medical men, who went a little beyond their last in insisting upon this mode of preventing percolation, which they thought would produce fever. All this enormous additional expense was incurred not only for nothing, but it had *exactly the effect the doctors intended it to prevent.*

Digitized by Google

They *cut through the water-tight stratum, and gave the water access to the sand below,* by which it is conveyed under the embankments and all through the country. .Had only so much earth been excavated as would have made the embankments, and the principal part of the water been carried above the level of the ground, about two-thirds of the cost of excavation would have been saved, consequently it would have been done in one-third of the time, and the returns have been received so many years sooner. If this and some other mistakes had not been made, the work would have been returning at least 20 per cent. for the last eight or ten years. I must, however, mention another fundamental mistake,—the delay in building the *permanent* weir at the head of the canal, the works being to this moment dependent upon the *temporary* dam, which has to be renewed after every monsoon, and is liable to fail at any moment when it is most wanted. In fact, it may properly be said, that this great work has neither head nor tail to it, no reliable work to secure the water being thrown into it; and in respect of the irrigation, the distribution works incomplete, and in respect of the navigation, no communication between it and the river. Yet there is nothing whatever to prevent the whole work being made in every way most complete both for irrigation and navigation, nor even to prevent its being made to irrigate a far greater extent of land than it was intended for. The excavation, owing to what I have mentioned, is so enormous, that an immense body of water may be conveyed by it. If money is allowed for its completion, I am satisfied that at a moderate further expenditure it may be made to return 20 per cent. upon the whole capital. The mischief of thus beginning and not completing a work, extends far beyond the mere waste of money ex-

Digitized by Google

pended on it; its effect in furnishing those who are seeking for them with objections to such expenditure, extends to almost the whole of India. I must also refer to the work on this canal that was injured last year. *It is most urgent that, at whatever cost, such evils should immediately be corrected.* The mischief of having to close the canal in the midst of a crop is most fatal, shaking the confidence of all landowners in the works. The real cause of the injury to that work was its being built entirely of brick, instead of the brick masonry being covered with large stone; good stone is procurable at Hurdwar, and this mistake may, therefore, be easily corrected. There is another reason why this work has not been so productive as it ought. It is, that the navigation has never been put into an effective state. The following are its defects as a navigation:—1st.—Boats cannot at present pass from it into the river. 2nd.—The bridges are most inconveniently low. 3rd.—The towing paths are not carried through the arches. 4th.—The current is too strong. 5th.—The lock-channels have such sharp curves that boats of the length of the locks cannot go through them. 6th.—The entrances to the lock-channels are made at too great an angle with the canal. 7th.—The fall of the canal is continued quite to Cawnpoor, so that a large stream must always be kept flowing to waste in order to make the canal navigable near its end. The last twenty or fifty miles ought to be reduced to dead levels by locks, so that the canal would be kept navigable without any expenditure of water below where it was wanted for irrigation, excepting the trifling quantity required for lockage. From these defects, this, certainly without exception, the finest highway in the world, is not used to one-fiftieth part of the extent it would be were it free from them. The loss of this to the irrigated tracts is incalculable. Could

Digitized by Google

they ship their wheat, gour, &c., direct for Calcutta, even with the disadvantages of the river, much of it might be brought to this market, which is quite out of the question if there is even fifty miles of land carriage. Happily all these objections can be perfectly removed, when not only would several lacs (a lac is £10,000) of additional revenue be obtained from the canal, but a new value would be given to all the products of that tract, and consequently to the irrigating water.

Thus all the works necessary for the completion of this incomparable project can be effected at no excessive outlay and in a short time. And not only so, but it is capable of vast expansion, far beyond its original intention. It has been stated in the newspapers that a gentleman is now trying to form a Company for the purchase and completion of this project. I only hope that, either in that way or by the Government, a work of such prodigious value and importance will not be allowed any longer to remain in an incomplete state, when there is really no shadow of a reason for it. It would not be so, were it in the hands of Commissioners who were responsible to the public for the effective management of the funds entrusted to them.

This work, therefore, is no exception to the rule that hydraulic works in India do not require to be supported by oppressive and debilitating taxes. Works that will yield from 20 to 50 per cent. can stand on their own legs.

Digitized by Google

III.

Memorandum written by MAJOR-GENERAL SIR A. COTTON, to accompany the printed "Reply" of SIR P. CAUTLEY, K.C.B.—Document No. 4.

The two points which SIR ARTHUR COTTON wished to urge were, 1st, an apology for the free style of his *Report* (No. 1), *on the ground that it was a confidential paper;* and 2nd, that the matter dealt with is not a mere personal question, but one of vital importance to India, and to the whole British Empire.

MEMORANDUM.

I MUST beg the readers of my paper on the Ganges Canal, printed in this pamphlet, to remember that it was entirely a *confidential paper*, written solely for the information of the East India Irrigation Company, without the least intention that it should be published—nor would it under any circumstances have been, excepting at the request of Sir Proby Cautley, to accompany his reply. I trust this will be considered a sufficient apology for the freedom with which I have written about these most important works.

The circumstances under which the Report was written were these. I was employed by the East India Irrigation Company to examine two extensive projects of Irrigation and Navigation in Behar and Oude, which had been proposed to them by the Government of India. This took me into the immediate neighbourhood of the Ganges Canal, and I could not but see that it was of the first importance that I should try to benefit by the results of the experience of others in those works.

Digitized by Google

I also found that this objection was everywhere encountered—viz., that those works, though they had been of unspeakable value in saving life in the famine, *had not returned a fair percentage in money.* The main reason of this was, of course, obvious enough—viz., *that the works had not been carried out;* that while an enormous expense had been incurred in head works, so as to provide for the irrigation of 1½ millions of acres, the petty distributing channels had only been cut to an extent to lead the water to 300,000 acres; so that even in the famine not a fourth of the water was applied to the land. So also with the navigation; for want of a very small expenditure it was left in a most imperfect state; so that this, the finest highway in the world, 350 miles in length in one line, besides as much more in branches, was comparatively little used. But it was, of course, incumbent upon me to satisfy myself fully by inspection and inquiry on the spot, of the whole state of the case, so as to furnish my employers with the necessary materials for answers to objections to the new projects, on the ground of the small money returns to this. As I thus examined into the matter, I became more impressed with the vast capabilities of this tract, and that not only would the work make abundant returns if completed to the original design, but that there was nothing whatever to prevent its being extended so as to embrace the whole Doab; and that *no tract in the world would offer a more favourable field for the employment of capital.* I therefore wrote a full report to the Irrigation Company, pointing out, what I considered, the original mistakes in the project, how I would correct them, and how I would extend the works; for our long experience in works of the first magnitude, in Madras, had naturally given me great advantages; and our mistakes and successes there, in more difficult localities than the basin of the Ganges, had taught us many things that bore directly upon the case of these works. In doing this it was of course essential that I should give my employers my opinion on the subject in the most unconstrained manner.

My great difficulty hitherto, in fighting the battle of the improvement of India by public works, has always been the

Digitized by Google

determination of my opponents to prevent an *open* discussion of the subject. Incredible as it will appear to all, in the case of the Toombuddra works, every paper was published by the Madras Government (including what was written *against* the project), *except* my reply to the attacks that had been made upon it. And the same in Cuttack; all the papers on the subject of the Mahanuddy were included in a Government-printed pamphlet, *excepting* the report which I had made in obedience to the orders of the Government.* It will be understood that, after this, it is with extreme satisfaction I acknowledge the honourable and courteous proceeding of Sir P. Cautley in printing my letter on the Ganges Canal, with his own reply. I hail it as a new era in the course of Indian Public Works; and trust that from this time there will be a fair and open discussion of this question.

There can be now no possible question about the importance of this subject. It appears from Colonel Baird Smith's Report, that in the late famine the Ganges Canal provided food for 1½ millions of people for a year, and was, besides, the means of conveyance of vast quantities brought from other places; and that *yet* 80,000 *persons died*;† so that we cannot but conclude that but for these works several hundred thousands would have perished. Again, the old irrigated District of Tanjore now yields a revenue of £600,000 a year, just double what it did formerly; and the two newly-irrigated districts of Godavery and Kistnah yield each upwards of £400,000 a year, though the works are yet only half finished; while the other districts of India yield only £200,000 on an average. Of the Godavery District the Madras Government, in their Administration Report for 1860-1, say: "*The increased prosperity of the district is most marked in every way;*" and again, in par. 220, "*The present state of the district, compared with its state before the improvement, may be safely summed up as follows:—the revenue has been doubled, the goods traffic increased thirtyfold, the pas-*

* I should rather have said that my report is not included in the printed Government records respecting Cuttack, which I have.

† In one portion of the tract only.

Digitized by Google

senger traffic sevenfold, and the exports twelvefold;" and again, "*The importation of bullion in* 1860-1 *was* £191,000.

Again, the effect of the irrigation of Tanjore has been not only entirely to preserve that district from famine for forty years, while almost every other part of India has been visited with that terrible scourge repeatedly, but it has also two or three times thrown immense quantities of food into the surrounding districts, while suffering in an awful manner from drought.

Again, as one instance only on the other hand, Ganjam alone lost 250,000 persons from famine, solely from the absence of Irrigation and Navigation in that and the neighbouring districts.

These results leave no possible room for doubt, as to the dependence of the prosperity of India upon the regulation of its water for Irrigation and Navigation, and, consequently, of the incalculable importance of the public having placed before them all that can be said on the subject by different men, who have had experience in the matter, and that the continued suppression of what is written on one side of the question cannot but lead to incalculable mischief. The suppression of what is written by a man of experience on the subject, of course can only imply that what is published will not bear "adverse discussion," and must be bolstered up by keeping from the public important points of the question.

There can be no more proper project on which to discuss this subject than the Ganges Canal, both on account of its magnitude, incomparably the noblest hydraulic work in the world, and also on account of the continual demand of the public for the reasons why it has not yet yielded larger returns in money. Its unspeakably important results in saving hundreds of thousands of lives during the late famine, on the other hand, equally call for an answer to the question, what is wanted to secure from it the most extended results which it is capable of producing.

It is, indeed, a small matter which of two individuals is on the right side in such a question, but there is the most urgent

Digitized by Google

demand for the thorough examination of a question on which even the lives of the population, to say nothing of the duty and of the character of our Government, so greatly depend.

I cannot but, at the same time, express my extreme regret that, though without the slightest intention on my part, the course of events should have thus brought me into collision with a brother engineer, who has taken the lead in the great work of irrigating and navigating India.

IV.

A Reply by Colonel Sir P. Cautley, K.C.B., *to the Foregoing Memorandum—No.* 1, *and Extract —No.* 2.

I have before me a pamphlet *On Irrigation and Navigation in Connexion with the Finances of India,** and also a *Report on the Ganges Canal,*† both of them written by Major-General Sir Arthur Cotton, late Chief Engineer of Madras.

The former consists of an address to the Calcutta Chamber of Commerce, May 7, 1863.

The latter is in manuscript, very kindly lent to me by Mr. J. Westwood, the secretary of the East India Irrigation Company, with permission to print it as an appendix to this paper. It would appear that General Cotton was deputed by the Company to visit the district of Behar, and to plan a scheme of works to be executed there. Whilst on this duty, he appears to have proceeded to the Ganges Canal and its works, and subsequently to have drawn up the above Report, showing value in cash, expenditure required to place it in perfect order, &c., with a view of enabling the Company to make an offer to purchase. A communication to that effect was, as I understand, made to

---

* See preceding copy—No. 2—of so much of this pamphlet or lecture as related to the Ganges Canal.

† Private Memorandum—No. 1.

Digitized by Google

the Supreme Government of India in a letter dated July 27, 1863. A copy of Sir A Cotton's report was sent on the same date, with a letter accompanying it, from Mr. Westwood to Sir Charles Trevelyan, Financial Member of the Council of the Governor-General.

To obtain a perfect understanding of the pamphlet so far as it concerns the Ganges Canal works, it is necessary to read the Report. The pamphlet itself contains a very imperfect notion of the comprehensive views and strictures of the Major-General, and leaves after perusal a more favourable impression than is conveyed in his report to the East India Irrigation Company.

Before touching on the subject of either the pamphlet or the report, I must be allowed to observe—

1. From the date of the Ganges Canal works being actively commenced by order of Lord Hardinge in 1847, to the period of my leaving India in 1854, the director of the works had an unlimited expenditure of money; no check was placed upon this even during the second Sikh war. Since 1854, with the exception of that period occupied by the mutiny and its effects, Government has been fully alive to the prosecution of the works and the completion of the rajbuhas;—it has shown no remissness on these points.

2. The depth to which the excavation of the canal channel has been carried is stated to have been forced upon me by the proceedings of the Medical Committee! No doubt that the committee did, and very wisely too, urge the necessity, on sanitary grounds, of such an arrangement, but I should have done the same, in all probability, had the Medical Committee never existed, and for this my reasons will be given hereafter; but as I protest, in the first case, against the Government being accused of being the cause of delays which occurred under my management of the works, so in this, the second case, *I decline being relieved from General Cotton's disapprobation at the expense of the Medical Committee.*

3. *I take upon myself the whole and undivided responsibility of the projection of the works on the Ganges Canal. Blame for their defects rests with me alone.*

Digitized by Google

4. My project was *especially for irrigation*, as the calculations for discharge and capacity of channel very distinctly show; navigation was entirely subordinate. It was an artificial river, in contradistinction to a series of still-water reservoirs. Nevertheless, strictures are passed on the project *as if it had been mainly designed for the purposes of navigation;* at least, so the majority of readers of the report would imagine, and so, I must confess, I do.

5. General Sir Arthur Cotton remarks very justly in his pamphlet that, after thirty-five years of active employment on irrigation works at Madras, it is not presumptuous in him to give decided opinions on matters connected with irrigation. I hope that twenty-nine years of my life passed in active employment on works of irrigation in the North-West Provinces of India may be considered by him as giving me and my opinions *some claim for consideration.*

With these preliminary observations I now propose to take up *seriatim* the censures conveyed in Sir Arthur Cotton's *Report*, and reply to the charges of having been guilty of the "greatest "fundamental mistakes in the projection of the Ganges Canal."

These are stated to be in number five, the first being announced in the following words:—

"1. *The head of the canal is placed too high up, above a tract "which has a very great and inconvenient fall, and in which "there is a very heavy drainage from the sub-Himalayas, across "which the canal has to be carried.*"

The writer says the extensive works executed on the first twenty miles of the course of the canal from Hurdwar to Roorkee could not have been more expensive than the construction of a weir across the Ganges below the confluence of the Solani. He then goes on to state that a canal officer had informed him that he had taken two levels from the Futtyghur branch to the bed of the Ganges, and found it forty feet on each, while the fall of country is three feet per mile; hence he argues that, by establishing a weir over the Ganges, and by raising its water ten feet, a canal with a slope of six inches per mile would, in the distance of twelve miles, lead the

Digitized by Google

water out on the present level of the canal. The only objection to such an arrangement being the want of stone, and the loss to irrigation of "*that particular little patch of country about Roorkee.*"

Sir A. Cotton states that, by adopting his plan of anicut over the Ganges below the confluence of the Solani, seventy lacs would have been saved, besides all the loss and annoyance from the maintenance of so many heavy works.

The above is as sweeping a censure as could have been well devised; and when one looks at a map, what appears more easy than to take a short cut from the Ganges below the Solani junction, and to maintain a head-water by damming the Ganges?

Sir A. Cotton remarks, with apparent astonishment, that this has not even been discussed in the reports he has seen; and he will be still more astonished when he learns that all discussions which have taken place on the subject, and all experiments that have been brought to bear upon it, have resulted in *the inevitable conclusion that interference with the river in this part of its course would end in utter failure, and that the works would be breached and washed away on the occurrence of the first flood.*

An allusion is made by Sir A. Cotton to Colonel Baird Smith. The late Colonel Baird Smith, whose acquaintance with the Madras canals is amply displayed in his report, published in 1856, by order of the Governor-General, under the title of *The Cauveri, Kistnah, and Godavery,* and who was so closely connected with me in the Canal Department of the North-West, and latterly on the Ganges Canal, to the charge of which he was appointed on my leaving India, in 1854, fully appreciated the difference that existed *between the engineering difficulties of the Madras deltas and those of the high lands of the North-West Provinces,* and was quite satisfied that the projection of the lines of the latter *from the shingle, and not from the sandy tracts,* was the only true and feasible one.

There is no originality in Sir A. Cotton's proposal; it is an old and exceedingly natural one: *our experience, however, in*

Digitized by Google

connection with rivers of the nature of the Ganges and Jumna has shown that it wont answer. It has been tried in the Jumna, for the Western Jumna Canals; on the last occasion in 1827-28.

In referring to the report on these canals, printed in 1849, I find the following:—

"An attempt was indeed made by Colonel Colvin, in 1827-28, "to establish the canal head on the Jumna, at Kulsowra, about "forty miles below Dadoopoor. The levels would have answered "well enough, but the result of the experiment, which was "abandoned after the first year's operations, was merely to show "the difficulty of establishing such a work on the Jumna, or in "a similar stream, after it has left the gravel and entered the "wide and shifting sandy bed, so characteristic of the Himalayan "rivers."

There is a vast difference between the nature of the great Madras rivers on their approach to within sixty miles of the ocean, with all their deltaic attributes, and the Ganges and Jumna on their debouche from the Himalayas, which, at a distance of 1000 miles from the sea, run in valleys considerably depressed below the surface of the country, on a rapid slope, and over beds of sand of a shifting and treacherous character.

I will, however, endeavour to show by levels, as far as I can at this distance from all papers of reference, excepting the Report on the Ganges Canal, how Sir A. Cotton's line would be brought to bear on the high lands of the Doab (very inappropriately termed by him "Delta"). It is necessary that I should fix a starting-point from the Ganges below the confluence of the Solani, so I take the river at Sookurtal, just below Bhokurheri. In referring to the Ganges Canal Report, vol. i. p. 19, and to the Atlas, map 63, it will be seen that a trial section from a point on the old Ganges, twenty-three miles below Hurdwar, at the village of Badshahpoor, gave the following results:—

High land near	Kumbhera	83 feet	above level of high-water mark at Badshahpoor.
,,	Bailra	68 ,,	
,,	Futtyghur branch head, Jaoli	52 ,,	
,,	Chitowra	42 ,,	

Digitized by Google

Sookurtal is ten miles lower down the stream of the Ganges than Badshahpoor. Giving the lowest estimate for the slope on this distance as $1\frac{1}{4}$ per mile, we have $12\frac{1}{2}$ feet to add to each of the above numbers, as marking the elevation of the high land above the river at Sookurtal.

Jaoli, or a point near the Futtyghur branch head, is (see Atlas, pl. 4) 115 feet below zero, or the flooring of the regular bridge at Myapoor. $115 + 64\frac{1}{2} = 179\frac{1}{2}$ feet, which represents the depression of the bed of the Ganges at Sookurtal.

To descend to the level of $179\frac{1}{2}$ feet, the above plate in the Atlas shows that we must go as far south on the canal as Bhola, or to a point *forty-five miles from the Ganges at Sookurtal.* As Sir A. Cotton fixes his slope of channel at three inches per mile, this will require a further depression of $11\frac{1}{4}$ feet, so that the channel would not begin to operate as a line for irrigation until it reached Newarri, a town at the *ninety-fourth mile of the course of the canal* in the neighbourhood of Moradnuggur.

On Sir A. Cotton's plan of adapting the bed of the canal at its departure from the dam or annicut to the same level as its sill or wasteboard, the above distances would be modified according to the height of annicut, whether ten or fifteen feet—if the former, to the eighty-sixth ; if the latter, to the eighty-fourth mile.

It would not, therefore, be *the patch about Roorkee* to which the strictures refer, but *the whole of the Suharunpoor, Muzuffurnuggur, and the greater portion of the Meerut districts,* that would by this plan be deprived of the benefit of irrigation. So long as irrigation is given to a certain surface of country, it matters, perhaps, little to what country that irrigation is given ; but as my intention was, and my project was directed to, the irrigation of the above three districts, it appears rather hard that I should be found fault with for endeavouring to effect it.

To conclude my remarks on this first of the fundamental mistakes, I can assure Sir A. Cotton that the river between the Gurmuhtesur Ghat, 95 miles below Hurdwar, up to the confluence of the Solani, has had its due share of attention from me ; and it is from having given the subject so much attention that my conclusions have been arrived at.

Digitized by Google

Fundamental mistake No. 2 is thus written :—

"2. *The whole canal has been cut so as to carry the water* "*below the level of the surface, entailing a vast unnecessary ex-* "*cavation, and keeping the water below the level at which it is* "*required for irrigation.*"

That is to say, the writer imagines that, under my projection of the work, watercourses were to be taken off indiscriminately from the main line of the canal, for the purpose of irrigating the lands *immediately in its vicinity!* and that, consequently by deep digging no water for irrigation could be procured without machinery.

My reply to this is as follows :—The slope of the country being much in excess of that of the canal bed, the latter, at certain points, approaches the surface : it is from these points that the rajbuhas, or main watercourse heads, are taken off. From these points, the water, consequent on the great slope of country, is freely delivered over the surface ; and as the lines of rajbuhas are continued in one connected chain from the upper to the lower region of the canal, the water, so far from being kept "below the level at which it is required for irrigation," is delivered, or ought to be delivered, on the surface everywhere.

Experience has shown that in the North-West Provinces we cannot, with regard to sanitary discipline, maintain a high-water mark *above the level of the country* in the main channel. Water standing on raised banks leads to percolation and leakage, with the more ruinous contingency of breaches, from the excavations of otters, rats, and vermin of this description. We, therefore, do not project our main channels on Sir A. Cotton's design, but we gain equal benefits to irrigation by a judicious disposition of our watercourse heads. The diagram on the following page will explain the arrangement.

The medical officer (to whom Sir A. Cotton refers at page 45 of his Report) is quite innocent of interference in the matter.

I must observe, however, that although, on Sir A. Cotton's project and plan of canal making, there may have been "vast "unnecessary excavations," on mine, the excavations made have been quite necessary. In fact, in a protective point of view, the

Digitized by Google

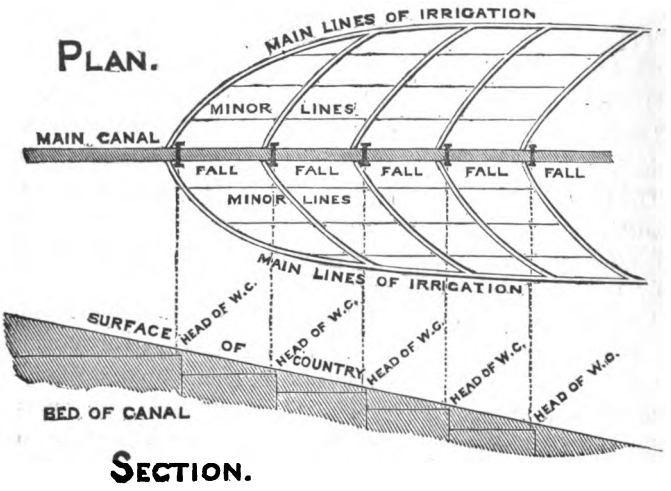
maintenance of the water in the canal channel as much as possible within soil, gives a very effective power of control over the supply.

Had the canal channel been excavated under Sir A. Cotton's orders, the evils of leakage or permeation would not have been prevented.

Generally speaking, the supersoil was good, but by no means of a nature impervious to water; occasionally it was of a very inferior description. Whether good or bad, however, the subsoil was sand to an unlimited depth. The good soil never extended beyond a depth of 8 or 10 feet, and was frequently very much less. In my original surveys, miles in extent of waste land were crossed rich in *Asclepias gigantea* (Mudar), the well-known attendant upon a sandy soil. The sand-hills and collections of drift, which are so characteristic of the Muzuffurnuggur and Meerut districts on those portions through which the canal takes its course, and which also abound on the high land and bank of the Ganges, from Sookurtal downwards, are all features connected with these deposits of sand. Not even the most

---

Diagram referred to in page 51.



Digitized by Google

moderate excavations, therefore, could have prevented the canal water from coming in contact with the sandy substratum ; and as it is on this *contact* that the leakage to which Sir A. Cotton draws attention depends, the evil—no doubt a great one—could not have been avoided.

Fundamental mistake No. 3 stands as follows :—

"3. *The whole of the masonry are works of brick, while the "most suitable stone for hydraulic works is procurable in the "Sub-Himalayas : this is a most inexplicable mistake.*" In another part of the paper, Sir A. Cotton writes—"the excellent "stone of Hurdwar ;" and in commencing his strictures, observes : —"*There is nothing more inexplicable than this in the whole "matter. I cannot find a word of discussion on this point in "the published reports on the project.*"

The strictures convey a sweeping condemnation on brick masonry, to which I by no means agree; nevertheless, where good stone is to be procured at a reasonable price, no man in his senses would select brick. The Sewalik sandstone, however, is of very uncertain quality, and is attended by beds of conglomerate of a similar character. It varies from extreme friability to a crystalline rock : in all the gradations through which it passes it is to be worked without any great difficulty. The unequal quality of the stone, however, and the preponderance of that of a very inferior order, renders it a somewhat dangerous material to be introduced on public works. The towns of Hurdwar and Kunkhul, the ruins of Badshahmuhal on the Jumna, those on the left of the Ganges, and numerous tombs and mosques in the vicinity of the hills, are built with this stone. The stone that is used is procured at considerable expense and with great difficulty ; hard portions are selected at distant and detatched points out of masses of the softer rock, and brought to Hurdwar and Kunkhul for the use of the stonecutters. As a rule, however, the Sewalik sandstone is notoriously inferior as a material for building. Stone of the quality that I should have selected (some of which has been used in the Myapoor Regulating Bridge) was much too expensive; and as my estimate of brick masonry is of a more sanguine nature than that of Sir A. Cotton, the heavy expense that the use of good

Digitized by Google

Sewalik stone for the masonry, or even for the floorings and walls of the falls and locks, would have entailed upon the works, determined me on the use of brick.

With reference to the above, I may quote paragraph No. 70 of Colonel Turnbull's Report on the Permanent Head-Works, Ganges Canal, November, 1862. Colonel Turnbull writes:—

"Some time before Colonel Rundall's visit to the head-works, "Mr. Login was directed to explore the neighbouring hills at "Hurdwar, for the very hard, heavy conglomerate adverted to "in his report: and having done so, in company with the pro- "fessor of geology in the Civil Engineer College of Roorkee, "Mr. H. B. Medlicott, he ascertained that such stone is only to "be found in detached masses along the hill-side, or in irregular "deposits, where it lies in its bed, and that the rock adjoining "it was quite unfitted for the proposed work nearer than ten "miles from its site. That the gradient for a tramway to "connect the works with the hills would be 1 in 13 feet, and "that, therefore, quarried stone of 3 to 5 tons weight, as pro- "posed by Colonel Rundall, could not be placed upon the "works at less than 8 annas per foot."

From what I hear, the reason why brick masonry has failed in the falls (or weirs, as designated by Sir A. Cotton) is, *that a pressure of water has been brought to bear upon the floorings, of a nature far beyond what I contemplated;* and I have the best authority for asserting that even in these cases the general character of the brickwork has been proof against the most exaggerated action of the water. *Failure has been attendant on badly-constructed work.* I am quite willing to agree with Sir A. Cotton that stone is better than brick, as a general rule, but I would prefer good brick to stone of doubtful quality.

Sir A. Cotton is mistaken in supposing that the boulders (or pebbles to which he refers) found in the bed of the Ganges and its tributaries have met with the fate that he bewails for the sandstone. I have always been a great advocate for the use of this material, having had before my eyes the gigantic ruins of Badshahmuhal, and the river face of that palace, the substructure of which was built of boulders (huge masses of

Digitized by Google

this species of masonry, having been undermined, lie prostrate in the bed of the river). A great portion of the solid work of most of the canal buildings in the Khadir have been constructed with this material, whilst the limestone boulders have subscribed to the limit of their extent to the mortar.

The implication that every useful material has been rejected and neglected by me in the construction of the works is, *to say the least of it*, not very complimentary.

Fundamental mistake No. 4 is worded as follows:—

"4. *The whole of the water is admitted at the head, so that "some of it is conveyed* 350 *miles to the land it irrigates, while it "might have been obtained at a sufficient level at a distance, say, "of* 50 *or* 100 *miles.*"

With the strictures conveyed in the first fundamental mistake, Sir A. Cotton states that at two different points on the Ganges, he has been informed that the difference between the level of river bed and high land is 40 *feet.* He then attempts to show how, by carrying a canal for 12½ *miles*, with a slope of 6 inches per mile, he could, by an annicut or dam of 10 feet elevation, supply water for irrigation on surface levels. He now, under the head of his fourth fundamental mistake, illustrates his argument by an imaginary case, where the backbone of the Doab (or delta, as he calls it) is 50 *feet above the bed of the river*, where his dam or annicut is raised 15 feet, and where the slope of the canal channel is 3 inches per mile.

Thus:—

Total difference of level between river and land	50 feet.
Height gained by weir	15 ,,
	35 ,,
Ditto, by canal, having a less slope than the land by 1¼ foot per mile, 28 miles, at 1¼ =	35 ,,

In both these cases, it will be observed that the site of the wasteboard of the dam or annicut, whether in that of 10 feet elevation or in that of 15 feet, and the bed of the canal at the point of departure, are on one and the same level. Sir A. Cotton, I presume, therefore, to obtain a water supply, contemplates some additional elevation raised on the top of his annicut. The

Digitized by Google

above two examples are intended to show the absurdity of my proceeding for a canal head to Hurdwar, when a supply could so easily have been procured from points so much more accessible. On the 50 feet difference of level (illustration just given) he estimates the cost of the annicut over the Ganges at 5 lacs of rupees, and goes into detail of the enormous saving that his plan would have effected. He states, "*that in this "case, therefore, instead of bringing the water, suppose,* 250 *miles "from Hurdwar to* 100 *miles above Cawnpoor, it would only "have been conveyed* 28 *miles, and there would have been a "saving of* 225 *miles of canal against the construction of a weir. "The cost of the latter might be* 5 *lacs, and that of an excavation "of, suppose,* 50 *square yards of section, say, at* 1½ *anna per "yard, or* 9,000 *rupees a mile, would be, for* 225 *miles,* 20 *lacs.*" I understand from the above, which is not very clear, that Sir A. Cotton proposes to terminate his 28-*miles cut* at a point 250 miles below Hurdwar; that he estimates the cost of a dam over the Ganges at 5 lacs of rupees; and that, having deducted the 28 miles of *his excavation* from the 250 *of mine,* he places the cost of the dam against my 225 (250 – 28 = 222?) *miles* of excavation, the one being 5 lacs and the other 20! *What can be the meaning of this?* If he intends to start from the 250 *miles,* thereby saving all the money expended up to that point in my project, he must place the difference of cost paid in juxtaposition. For instance:—

Sir A. Cotton's dam	5 lacs.
Cost of cutting of canal from dam to the end of the 28th mile (or to my 250th mile)	?

These two items must be set against the cost of my works from the head to the 250*th mile.*

The irrigation of the whole of the lands above this point would, of course, be thrown out; but General Cotton points out this advantage in so doing—"*It would provide for a large "additional supply of water beyond what could be obtained from "the present head, for it would secure the water draining out of the "sands of the river on this* 225 *miles, besides any flowing into it "from the small affluents that water the river in that space.*"

Digitized by Google

"*The same might be done with the Jumna,*" he goes on to say; "*and thus, at a small cost, three or four times the land "might be irrigated that is at present provided for. Probably, "one or two such additional heads for each of the rivers, Ganges "and Jumna, might be cut with advantage.*"

Sir A. Cotton's language is obscure, and I may possibly misunderstand him; but there is no questioning the fact that *the object that I wished to attain of irrigating certain districts* is entirely ignored, and a project of his own is made the vehicle for strictures on mine. It is unnecessary to recapitulate my objections to Sir A. Cotton's schemes; these are stated in my reply to his first fundamental mistake. *It will be found more easy to propose weirs and dams on the sandy tracts of the Ganges and Jumna than to execute them.*

The fifth and last fundamental mistake is as follows:—

"*5. There is no permanent dam across the river at the head of "the canal, so as to secure the supply of water, but temporary "works are thrown up after every monsoon, which are liable to be "swept away, and have been swept away, at the very time when "they are most wanted.*"

In the canals in the North-West Provinces, the supply for which is drawn from the great rivers at their debouche from the mountains, this supply is obtained in the manner noticed by Sir A. Cotton, viz., by *temporary spurs and dams* thrown out into the main river. No doubt that this is a very imperfect method of securing the object in view; but if successful, as it has been on the Jumna, the device is, at any rate, an *economical* one. Even on the Ganges Canal, the annual cost, estimated at 20,000 rupees (which represents a capital of 4 lacs), is economical, *as far as the mere work is concerned.* In adopting this course on the Ganges Canal, however, and being guided by experience gained on the Jumna, I was by no means satisfied that, in dealing with such large masses of water, works of a more permanent nature would not *ultimately* be called for. This was a matter left to be determined by *experience.* I am not in the habit of jumping at conclusions, and putting the Government to expenses which are not proved to be necessary; and I, therefore,

Digitized by Google

left this "fundamental mistake" to be corrected by my successors, whose observations on the difficulty, or otherwise, of maintaining the supply by the usual method adopted in these provinces, would lead them ultimately to arrive at *satisfactory conclusions.* The question, however, of throwing a permanent dam or annicut over the Ganges at the point desired is, by no means, so simple as Sir A. Cotton imagines. His experience, great as it is, is connected with rivers *of an entirely different description to that of the Ganges in its debouche from the Sewaliks. Here we have heavy slopes with large masses of water pouring down with overwhelming violence; there he has much larger bodies of water, but on very much smaller slopes in connection with a true delta.* Sir A. Cotton gives the following statement of discharges:—

Ganges	25,000,000	cubic yards per hour.
Godavery	200,000,000	,,
Kistnah	160,000,000	,,

Or, translated into cubic feet per second—

Ganges	187,500	cubic feet per second.
Godavery	1,500,000	,,
Kistnah	1,200,000	,,

And states that the construction of the dam over the Ganges, at the level head, "*is still put off, apparently under the strangest "fancy that such a work is one of most serious difficulty, "though it is nothing to the works of the kind that have been "executed in Madras.*"

I am not at all satisfied with arbitrary statements of "*millions of cubic yards per hour,*" without knowing *on what they are based.* It is possible that the amount of discharge during the monsoon, at the point where the permanent dam at the Ganges Canal head is to be built, may be correct. Nevertheless, small as this is in comparison with those stated by Sir A. Cotton, as appertaining to the Godavery and Kistnah, *the Ganges has a slope of bed far beyond its Madras compeers.* This slope makes all the difference; and although I believe *a permanent dam may be constructed without fear,* and I have no doubt that, if it is so, it will be of infinite benefit to the canal, and of great relief to the mind of the engineer, the cost of the work will be, not as Sir A. Cotton

Digitized by Google

states, £30,000 or £40,000, but, as estimated by the officers on the spot, at nearly double that sum; and, if cut stone is used, as demanded by Sir A. Cotton, the work will cost very much more. The Ganges, moreover, will not *quietly submit to discipline of the nature proposed,* and breaches will annually occur at points not very easily to be approached. Although, therefore, I admit that a permanent dam is desirable, and that the annual expenses that this will entail are far preferable to interruption to the canal supply, I consider that we have used a wise discretion in not calling upon the Government to spend large sums of money *without having ascertained beforehand the positive necessity for so doing.*

This concludes my remarks on the five fundamental mistakes, or, as Sir Arthur Cotton calls them, *the greatest fundamental mistakes in the project.*

I shall now proceed to reply, *seriatim,* to the different *minor mistakes,* of which Sir Arthur Cotton notes fourteen, prefacing them with the following paragraph :—

"*But besides these fundamental mistakes in the projection,* "*there are the following minor, but still important ones :*—"

Minor mistake No. 1.—"*All the weirs are made of a length* "*corresponding with the full breadth of the canal, while they* "*need not and ought not to have been more than one-third of that* "*length, entailing a more than double expense in their construc-* "*tion, besides other destructive evils which will be more fully* "*explained.*" This is a question so intimately connected with "No. 4 Minor Mistake," that deals with the slope of the canal bed, that I shall merely remark that the breadth of the falls is *considerably more* than the breadth of the canal channel. In the larger falls there are eight openings or water-ways of 25 feet each; each opening has arrangements at the upper level or sill for the application of planks or sleepers to a depth or height of 7 feet. The fall on the lower face is divided into four chambers by walls, so that in the event of repair being required to a chamber flooring, the object can be effected by closing the upper water-ways connected with that flooring. The power of opening and closing these upper water-ways by sleepers gives

Digitized by Google

the means of regulating the passage of water on the falls, and of guarding an injured chamber against further injury. The design contemplated not only *great strength* to overcome the effects of such large masses of water, but *ample means for providing against accident* by the separate chambers. Sir A. Cotton observes that the breadth might have been reduced to one-third, and that the works have cost more than twice what they ought to have done. A water-way of 66 feet in width (or one-third of the dimensions given) would have been a somewhat confined passage for so large a volume of water, laying aside the fact that we should have been deprived, under such a width, of alternative channels, and of the means of maintaining the canal supply should any accident happen to the work. More will be said on the subject of these falls when I discuss the question of the slope of bed.

Minor mistake No. 2.—"*These weirs (falls) are placed on the "direct line of the canal, while the navigation lines and the "locks are placed out of the direct line, thus compelling the whole "of the traffic to go round instead of the irrigation water.*"

I understand by this that Sir A. Cotton would have given a turn to the main canal at each fall, and allowed the navigable channel to proceed in the straight direction. In other words, the main body of the water would have been made subordinate to a little channel. Sir Arthur Cotton writes after this fashion in disapproving of my plan :—"*There is no reason for this : the "navigation was the thing to be cared for ; it was a matter of no "consequence that the water should be led round by a circuitous "route,*" &c. The simple consequence of leading large masses of water round an object, or turning them from their course, is to lead to *very serious action upon the channel.* At any rate, I have no doubt that the plan adopted was the proper one—viz., to carry the main channel and large body of water direct, with the navigable channel, or small body, in the circuit. Sir A. Cotton goes on to say, "*that the boats now have to get "out of the current which leads direct to the weirs, and to turn "into the side channel, and, of course, not without danger. Some "boats have thus been carried over the falls, and several lives*

Digitized by Google

"*have been lost.*" Had Sir A. Cotton referred to my report, and to the plans that accompanied it, he would have found in the former, at pp. 297, 311, 312, vol. ii., and in the latter at plan No. 30, also p. 204, vol. i., that full attention had been given by me to the danger to which he refers. It would have been *impossible, had my project been followed,* for either boats, rafts, or anything else, to go over the falls: the bridge of boats, for which arrangements were made in the permanent buildings on the right and left of the main channel below the mouth of the navigable line, would, had they been in position, have prevented accident. *The loss of life, and the absence of these boat-bridges, are facts which are entirely new to me.*

Minor mistake No. 3.—"*The whole cut has too great a fall* "*in its bed—from* 15 *to* 12 *inches per mile—which, with a depth* "*of* 10 *feet which it was intended to have, gives a current of* $2\frac{1}{2}$ "*or* $2\frac{3}{4}$ *miles an hour, which is too much both for the bed and* "*banks of the canal, and also for effective navigation*"

Sir Arthur Cotton considers the above as a "*minor, although important mistake,*" whereas it ought to have been placed at the head of his great *fundamental* ones. Upon it has depended not only the *interruption to irrigation,* but *the injury to the masonry falls,* the constant repair of which has led to repeated stoppages of the supply—at times, unfortunately, when irrigation was most demanded. Sir A. Cotton has indorsed the view taken by the public press, that the great depth of excavation of the canal channel was the cause of difficulty in working the canal for irrigation; whereas he must have well known, by visiting the works, that the want of irrigation was caused by the want of water, arising from the frequent stoppages to the supply, for the purpose of repairing the falls.

I have no hesitation in admitting that, with so large a volume of water running at such great depths, I have projected the canal bed on too heavy a slope; it has been the cause of all the disasters which have occurred, the source of constant anxiety, and it has brought the canal into a position which in all probability is not exaggerated by Sir A. Cotton.

In self-defence, however, I must explain both to the readers

Digitized by Google

of the Pamphlet and the Report, that the projection of the slope of 15 inches per mile was determined on reasonable grounds, viz., that high as the slope was, artificial means might be applied so as to render the effects arising from it innocuous. The means which I adopted were, strengthening the floorings and tails of bridges by heavy and extensive boulder-work, and by reducing the evil to a minimum by offering as many checks as possible to retrogression of levels (*Ganges Canal Report*, vol. ii. p. 158.) These artificial means have entirely failed, and the consequence has been that the great slope given to the canal bed has acted in its fullest effect.

I must now explain the principles on which my line of action was determined. In calculating the area of a section required for the carriage of a given quantity of water, it will be quite clear to everybody that we have the alternative of a narrow channel with a rapid slope, or a wide channel with a small slope. The first may be maintained by artificial expedients, the latter is independent of them; the first can be constructed at a moderate cost, the latter at a very high one. For instance, in the case of the Ganges Canal from the Roorkee Bridge to the Bolundshuhur branch-head, say a distance of 91 miles, the slope of country is 177$\frac{3}{4}$ feet; by the projection of slope which I gave to the canal bed of 15 inches per mile, I obtained an open canal, with a moderately wide excavation, with a superfluous fall of 64 feet, which was overcome by eight falls of 8 feet each. The same line projected on a low slope, say that determined by Sir A. Cotton of 3 inches per mile, would demand an excavated channel of much greater width, with a superfluous fall of 155 feet, to be disposed of by masonry descents, so that the difference in cost of the low and the high slope would be enormous. I allude to the above arrangements with reference to the channel, with no intention of excusing myself, but to show that the grounds on which I acted were reasonable.

We have never before dealt with such large masses of water in irrigation canals where a constantly-running stream is indispensable. It is with these large masses that our difficulties have arisen. I see no remark in Sir A. Cotton's report tending

Digitized by Google

to show that he looked upon them as affecting the project; so far from it, that he proposes a depth of 18 feet of water without the slightest hesitation, and without the most distant idea of having difficulty in dealing with it.

From what I have said above, there will be no difficulty in understanding that the action on the falls depends on the current obtained from the rapid slope of the bed: take away that rapid slope, and the evil ceases. The method which I adopted of dividing the head of the falls into eight separate bays of 25 feet each, with grooves adapted to the establishment of sleepers, offered the means of reducing the width of the water in its passage over the falls to a dimension less even than that demanded by Sir A. Cotton.

I look to the improved plan of falls adopted in the Baree Doab canals, rather than *to the weak projections of Sir Arthur Cotton.* I believe that the fall in the form of an ogee which I have adopted requires modification, and I have no doubt that this will be made with due consideration to the masses of water with which we have to contend. With regard to the use of slabs of stone on the floorings in substitution of brick on edge, the only objection is expense. The country below Roorkee is far distant from quarries, and the cost of stone will be very heavy; nevertheless, I would recommend stone, and, if procurable, slabs from the quartz rock of Delhi.

In closing this part of the subject, and in referring to the falls and their brick floorings, to which Sir A. Cotton objects so strongly, I must observe that to remedy the defect of heavy slopes, sleepers or planks, to which I have before alluded, have been permanently established at the heads of the falls, so as to reduce the slope above stream. This remedy, while averting one danger, has given birth to another not less serious. The increased head-water has severely tried the works, and some of them have given infinite trouble and anxiety. No doubt that badly-executed masonry work has been brought into prominent relief, and that those works with bad brick masonry have suffered; but if there were no other mark that Sir A. Cotton's condemnation of brickwork is too sweeping, it would be shown

Digitized by Google

by the fact that where precisely similar falls have been *well built, they have stood uninjured.*

Minor mistake No. 4.—"*The canal has been terminated at "Cawnpoor, instead of being carried on* 120 *miles to Allahabad, "where the Jumna and Ganges and the river navigation begin "to be effective throughout the year.*"

As my project was for the *irrigation of the Doab* as far south as Cawnpoor and the districts lying parallel, a *navigable line to Allahabad has not much to say to it.*

Minor mistake No. 5.—"*The slope of the canal is continued "to the end at Cawnpoor, so that to keep the navigation open, "there must be a large body of water continually pouring to "waste in the river.*"

I must repeat that my project is for *irrigation,* and as such, it is indispensable that there should be a running stream to the lowest rajbuha head, and to obtain this stream, I imagine that slope is necessary. It is only when the demands for irrigation are small that water flows to waste in the river. Had Sir A. Cotton visited the terminus *during a season of drought,* he would have found the canal dry, in all probability, *at its extreme end,** it being a rule in the canals in the North-West Provinces to sacrifice navigation (which is a mere secondary object) to the wants of the agriculturist in times of drought.

Minor mistake No. 6.—"*The bridges are so low as to prevent "a fully-loaded boat passing under them.*"

This is only true as regards the *lower half* of the canal; *the bridges on the upper do not, I believe, interfere with the passage of boats.* On the lower part, my minimum height between high-water mark and the soffit of the arch was 5 or 6 feet, ample for the passage of such boats as were used on the canal. The high-water mark of my project, however, has been, in late years, much exceeded—I hear, to the extent of 2 feet in the Cawnpoor terminus—so that there must have been great interruption to the passage of boats. The quantity of silt

* In seasons of heavy drought a system of rotation is adopted (*tateel,* as it is called), by which water is given for irrigation to every village in its turn.

Digitized by Google

brought down from the canal bed south of Roorkee has no doubt been deposited in different parts of the canal bed, and acted in elevating the high-water mark. Viewing the question, however, as Sir A. Cotton views it, the bridges, no doubt, are opposed to general navigation.

Minor mistake No. 7.—"*The towing-paths are not carried "through the arches of the bridges, so that the line has to be thrown "off at every bridge, that is, at every* 3 *miles.*"

Both this and the last mistake would, no doubt, have been serious ones had *navigation* been the *leading* feature of the project, but *this* was *not* the case (*vide Ganges Canal Report*, vol. ii. pp. 319—321).

Minor mistake No. 8.—"*The lock channels have such sharp "curves that boats of the length of the locks cannot pass through "them.*"

The lock channels leave the main line at an angle of 18 degrees (*vide* plan 30 of the Atlas). I was not before aware of sharp curves existing, nor of the defect pointed out by Sir A. Cotton (*vide Ganges Canal Report*, vol. ii. p. 308, *et seq.*).

Minor mistake No. 9.—"*No arrangement has been made for "the disposal of the silt.*"

None further than to pass it off by the escapes and termini.

Minor mistake No. 10.—"*There are no connecting navigation "lines between the different main branches, so that boats can only "get* across *the tract by going all the way up to the point where "the branch and the main line divide.*"

This is treating the project as one for *navigation*, which *it was never intended to be.* My project, however, alludes to a navigable channel from Moradnuggur to the Jumna, or to the Hindun (*vide Ganges Canal Report*, vol. i. p. 219).

Minor mistake No. 11.—"*The Solani Aqueduct is made of the "full breadth of the canal above, and of the full length of the "breadth of the river below, whereas it might have been made of "* $\frac{1}{3}$ *of the breadth of the canal, and its length of about* $\frac{1}{2}$ *of the "breadth of the river, reducing its cost to perhaps* $\frac{1}{4}$ *or* $\frac{1}{5}$ *of what "it has been.*"

In chapter ix. of my *Ganges Canal Report*, vol. ii. page 411,

Digitized by Google

I have entered fully into the merits of the questions now brought forward by Sir A. Cotton. The width of water-way for the Solani was determined on observations carefully made during heavy floods; and, with reference to the catchment basin of the river, it has nothing whatever to do with the width of the river. The river as now existing is limited to the water-way of the aqueduct, whereas, previously to the establishment of this building, its course was in quite a different direction. Rivers, or mountain torrents like the Solani, do not run on one defined course; they play all sorts of vagaries on a widely-extended Khadir, now showing themselves on a wide shallow bed, then in a number of minor channels; and this was the character of the Solani before it was restricted to its present course. From the authoritative way in which Sir A. Cotton writes, I presume that he has looked deeper into the question than I have, and that he has not brought this censure to bear on me without having well examined the merits of the case. His method of writing, however, conveys an impression that, *without any scientific inquiry*, I had determined the width of the water-way by the existing width of the river, and that the width of the aqueduct channel had also been obtained by a similarly rude and simple process. Sir Arthur Cotton, however, is here mistaken. Both the width of river water-way and the width of canal water-way on the aqueduct have had much care, thought, and attention devoted to them; and this does not deserve to be treated in the *ad captandum* language of Sir A. Cotton's Report. It was indispensable that the Solani Aqueduct should be placed *beyond the reach of accident from the most violent floods, as upon the maintenance of this work depended the maintenance of the supply.* I do not think that, with reference to the volume that the Solani Valley throws upon the works, and especially to floods like those of 1845, the water-way could, with safety, be diminished.

The water is conveyed on the aqueduct by two channels of 85 feet each, each channel being constructed on separate foundations; the channels have sleepers adapted to them, so that in case of accidents or danger to one of the chambers an alternative

Digitized by Google

line is offered, by which the supply is maintained in the other. I did not consider myself justified in attempting a rapid run of water over this elevated embankment, nor would this have suited the plan of the double chambers, which I believe to be a most valuable adjunct to the undertaking. I do not think, moreover, that a body of water equal to 6750* cubic feet per second could, on an embankment at an elevation of 27 feet, be allowed to run on extraordinary velocities; but here again I find that Sir Arthur Cotton lays no weight on masses of water like those I have to deal with. He gives me, as an example that I might well have followed, the Gunnarum Aqueduct—a work carried over a minor branch of the Western Godavery—the channel of which is 22 ft. in breadth, and which has a capacity of channel equal to the carriage, at a depth of 4 feet, of from 500 to 650 cubic feet a second! (*Vide* Baird Smith's *Report on the Cauvery, Kistnah and Godavery:* Smith, Elder, & Co., 1856.)

With reference to the Gunnarum Aqueduct, the late Colonel Baird Smith, in pp. 114—117 of the report above noted, draws attention to points which are very suggestive, as bearing upon Sir Arthur Cotton's strictures upon my operations. Colonel Baird Smith says:—"It appears to be possible to secure founda-"tions on the rivers of Southern India, with their very low "slopes, by means which, with our own experience of the rivers "of Northern India, we would be justified in pronouncing "utterly inadequate, and with which, in fact, we would never "dream of operating, since they would inevitably fail on the "first serious trial. I therefore conclude that, so far as the "foundations are concerned, previous experience in other and "similar localities is sufficient to warrant their being pronounced "trustworthy. But the provision for the passage of the floods "seemed to me inadequate. Within a few months, or possibly "weeks (for I forget the precise date), after the aqueduct was

* The Thames, in the parts removed from the influence of the tides, on the average, has a volume equal to 1357 cubic feet per second (*vide* Weale's *London and its Vicinity*, p. 7), or one-fifth of the volume of the Ganges Canal.

Digitized by Google

"finished, a flood rose, as I understood, not less than 5 or 6 "feet over the level of the tops of the parapets, thus burying "the whole structure under water. The height of the flood "must have been about 30 feet, and it was no doubt an extra- "ordinary one; but not so much so as to place it beyond the "region of contingency, for which, in projecting such works, it "is necessary to make some adequate provision. The sectional "area of channel for such a flood, as provided by nature, is, "approximately, about 72,000 square feet; that provided by "the engineers is considerably over-estimated at 30,000 square "feet. It is only necessary to look at the elevation of the "aqueduct, and to note the proportion between the solid and "permeable surfaces presented thereby to the stream, to make "it self-evident how serious an obstruction to the current the "work must be in all considerable floods, but especially in those "where the flood-level rises high on the parapets. I must con- "fess my own conviction to be that this aqueduct will be a "constant source of anxiety, and that the probabilities are in "favour of the repeated occurrence of formidable accidents to it. "That this anticipation is not imaginary has been proved by "the experience of the past season, and I quote a few words "from a letter, under date 19th August, 1853, from an officer "intimately connected with the works, showing that already "the dangers to which the structure is exposed have exhibited "themselves in a very serious form:—'The great aqueduct, by "'the way, has received considerable damage, the high and "'heavy side wall having broken and fallen flat upon three of "'the arches, which are thereby cracked considerably, and one "'of them very badly. This was caused by very high freshes, "'which came down at an unprecedentedly early period. The "'Vegaishwaram head sluice (at the annicut or dam) was also "'partly destroyed; the ruins of its adjoining lock I believe "'you saw. The Kistnah, also, rose to a prodigious height, and "'flooded vast tracts in Masulipatam and Guntoor, so that the "'people had to mount on the roofs of their houses and on carts "'for safety. There was a regular river 9 miles wide, north of "'Bezwarah, where the land dips from the banks of the Kistnah.

Digitized by Google

"I have added details not directly connected with the "aqueduct, with the view of showing that the floods on this "occasion were evidently paroxysmal, being rather grand "*debacles* of water than even freshes of the order termed extra- "ordinary. I do not advocate perfect provision against such "*debacles*, for the expense would be enormous; and it is "preferable, I conceive, to run the risk of such very rare "events, and to be prepared to repair the injuries done to "them, rather than to execute works which may not be required "more than once or twice in a century, and the provision of "which would prove, in all probability, a total bar to progress, "by the gigantic scale of expenditure it would necessitate. It "is because the aqueduct seems to me to be inadequate to its "task of passing these high floods, which often occur, that I "have expressed the foregoing opinions; and though I have "a high respect for its projector, it would, I conceive, be "shrinking from my duty were I not to express them frankly. "For occasional accidents, when such rivers as the Godavery "are being dealt with, every reasonable person will be pre- "pared, and will view them with due consideration; but it is "to more than common risks that a work with the proportions of "the aqueduct is exposed; and I see but little chance of the con- "sequences being evaded while these proportions are maintained."

I must have reasons, at any rate, given me before I am brought to believe that I have been wrong in my projection of the Solani works; *and I find none in Sir Arthur Cotton's statement.*

Minor mistake No. 12.—"*The breadth of the canal at the "lower end is much too small for a large traffic, such as there "would be if the navigation were in an effective state.*"

With this my *irrigation* project is not concerned.

Minor mistake No. 13.—"*The slope of the sides of the canals are much too steep.*"

I do not agree with Sir A. Cotton.

Minor mistake No. 14.—"*There is no communication between "the canal and the river at Cawnpoor; for though there are "double locks, the gates of the lower ones were not in repair. I "am credibly informed when they were in repair, boats were not*

Digitized by Google

" allowed to pass backward and forward, but if they entered the " canal were compelled to remain in it, because, as I was informed, " they often injured the plaster on the lock works."

To this I have no reply.

Having now gone patiently through the whole of Sir Arthur Cotton's Report, and replied to his censures with as much temper as I could be expected to maintain under such an infliction, I shall take the liberty of making a few remarks bearing on *the general question.*

I have in the early part of this paper stated under what circumstances General Sir A. Cotton wrote his Report. I heard accidentally of its existence early in November, and immediately applied to the secretary of the East India Irrigation Company for a copy, the report having been read by my correspondent in India in print. The secretary informed me that the document had never to his knowledge been printed; that it was a private paper* for the use of his Company, and that if it had been printed, this must have been done in India. He telegraphed to Sir A. Cotton to know whether he might provide me with a manuscript copy of the Report. This being acceded to, the secretary very kindly not only sent me a copy, but copies of his letter to the Government of India and to the Financial Member of the Governor-General's Council. The paper, therefore, came before me long after it was issued. I received it on the 13th of November, 1863.

So far for the history of the Report. Now to my remarks upon it; the delay of which is sufficiently accounted for by the above explanation.

One of the most extraordinary facts connected with Sir A. Cotton's censure is, that he declares that I had no reason for proceeding to Hurdwar and its neighbourhood for a head for the canal; that by going to the higher regions I had led Government into expenses in connexion with the mountain torrents which were preposterous; and that in so doing I had

* The MS. in my possession is headed—*Private Memorandum, by Major-General Sir Arthur Cotton, upon the Ganges Canal.*

Digitized by Google

committed an error which he considered to be the leading fundamental mistake—that is to say, the first of nineteen mistakes that I had committed in the design. He points out that the proper site for the head of the canal is from 50 to 100 miles south of Hurdwar, and below the junction of the Solani River with the Ganges.

Now, we must inquire on what grounds Sir Arthur Cotton has made this declaration. It would fairly be supposed that he had examined the topographical features of the country, and had carefully estimated the value of the Ganges River in its connexion with the shingle tracts and the sandy bed of the Khadir; that he had looked carefully to the nature of the rivers, and to the contour and character of the high country in the neighbourhood, with reference to those rivers, before he came to any decision on the subject, or at any rate before he became directly antagonistic to plans which had been drawn up and matured on the spot with the greatest deliberation. All this would naturally have been supposed—but what is the fact? Sir Arthur Cotton paid a flying visit to the Ganges Canal works, and (to use his own words)—"*I was informed by an "officer of the Canal Department that he had taken the level "from the Futtyghur branch of the canal to the neighbouring bed "of the Ganges in two places, and found it* 40 *feet in each.*' Without the slightest hesitation or scruple, Sir A. Cotton, upon hearing this, rushes at the conclusion noted in his Report, gives his high name to a summary condemnation of all my proceedings, and forwards to the secretary of the East India Irrigation Company a Report professing to be his deliberate views on the *fundamental mistakes* of my projection. In looking carefully through Sir A. Cotton's Report, I can find nothing but the statement made by the departmental officer to warrant his conclusion; *I can discern no sign by which he has been otherwise guided.*.

The point on the Ganges from whence Sir A. Cotton proposes to draw off his supply for the canal is by no means clearly indicated. I find that, he gives, as a terminus for a line of 28 *miles* in length, a point 250 *miles below Hurdwar*, but how

Digitized by Google

he leaves the Ganges on these conditions, I have not the most remote idea. He refers also to making a cut 12 *miles in length.* I presume that this must be intended to leave the Ganges not far south of the confluence of the Solani; but although I can't pretend to strict accuracy as to the precise level of the Ganges at that point, I believe that a cut having a slope of 6 inches per mile would not fulfil Sir. A. Cotton's conditions in a shorter distance than 50 *or* 60 *miles.* He refers in the latter part of his Report to heads taken off from the Ganges and Jumna 200 and 300 miles below the confluence of the Solani. In another place he states that by making a new head to the canal below the confluence of the Solani, "*far less expense will* " *be incurred than by correcting the works on the canal above* " *Roorkee. If these works, with the help of slight alterations,* " *will have a depth of water in the canal of* 3 *feet instead of* " 7 *feet, as at present, the cost of cutting* 12 *or* 15 *miles to form* " *a new head will be less than the substitution of new stone weirs* " *for the present brick ones.* The weirs across the Ganges will, " of course, be nearly the same, whether built at Hurdwar or " below the Solani."

How can this be? Is it to be understood that the cost of a dam, built on the deep and wide sandy bed of the Ganges, below the confluence of the Solani, will be the same, or nearly the same, as that constructed at Hurdwar over the stony bed of the river? To this conclusion we are inevitably led by the above extract; yet elsewhere Sir A. Cotton appears to think that the absence of quarries in the proximity of this lower dam might lead to additional expense.

The Hurdwar dam is estimated by Sir A. Cotton at a cost of *from* 30,000*l.* *to* 40,000*l.*

Looking further into the report, the dam below the confluence of the Solani is estimated at 5 lacs of rupees; and in the estimate appended to the report appears the following item :—

" *New head and weir near the Solani,* 100,000*l.*"

This includes both dam and cut from the river. These statements are somewhat contradictory.

In the early part of his Report, Sir A. Cotton states that if

Digitized by Google

matters had been properly conducted, the works "*might have* "*been yielding* 20 *or* 30 *per cent., or much more, for the last ten* "*years.*" Again he says: "*From the mere mention of these* "*defects of projection, it cannot but be understood how it is that* "*this work, in a tract of country with such prodigious natural* "*advantages, has been so unproductive for seventeen years from* "*its commencement.*"

The water was only passed over the Solani Aqueduct in a small body in 1854; and Lord Hardinge's order to carry out the works was only passed in 1847—that is to say, sixteen years ago!*

In smaller matters, Sir A. Cotton is equally unsatisfactory. For example: The supply of the Ganges Canal he states to be 8000 *cubic feet per second;* whereas the whole of my calculations for discharge and distribution are *limited to* 6750. In detailing the width of the Solani Aqueduct, he states it to be 66 *yards;* whereas it is 170 *feet,* or 56⅔ *yards.* His calculation of discharge of rivers is founded on what? *Millions of yards per hour may be easily written, but not so easily accepted by those who require definite data.* A calculation for loss by evaporation on a canal 40 yards wide, of 2 *cubic yards per hour,* which I observe in his Report, *is one of those extraordinarily cool dicta which defies all inquiry.*

In the Pamphlet, Sir A. Cotton states that "*the last* 20 *or* 50 *miles of the canal above Cawnpoor ought to be reduced to dead levels by locks.*" In his Report this is changed to 30 *or* 40 *miles;* but he states that the dead level is indispensable for navigation. Now, whether there are 20 or 50 miles of still water, it must be borne in mind that irrigation was carried down by me to within a very short distance of Cawnpoor, for the purpose of the tract of land lying between the Pandoo

* The ground was actually broken on the 16th April, 1842, under orders from the local Government; but it was not until the report of the sanitary committee had been received, and the inquiry as to the effect of the abstraction of the required supply for the canal upon the navigation of the Ganges had been completed, that the supreme Government determined, in 1847, on prosecuting the works to completion. (Vide *Ganges Canal Report,* vol. i. p. 63.)

Digitized by Google

and the Ganges; and as, on my projection for the discharge for irrigation, 8 cubic feet per second were given for each mile, it would follow that for 20 or 50 miles in length we should require a running stream of from 160 to 400 cubic feet per second. Unless Sir A. Cotton means that branches for irrigation are to be taken off from the canal to the right and left, above the 20 or 50-mile point, leaving the main line as a system of reservoirs, it is difficult to understand how water is to be supplied. Without a *running* stream, as Sir A. Cotton knows, I presume, irrigation cannot be maintained; and when the supply of water is limited, as it is on the Ganges Canal, especially at a distance of upwards of 360 miles from its source of supply, if navigation is to be insisted on, it will be at the sacrifice of irrigation.

The *problem* to be solved was, the delivery of 6750 cubic feet of water per second on the high lands of the Doab, and the carriage of this large body of water for the purposes of irrigation to a distance of 360 miles, without any additional supply being available, on the whole length of its course. The *difficulty* consisted in carrying that great mass of water across the Ganges Khadir and its numerous mountain torrents, and in regulating the distribution of the water by a channel so adapted to the required discharge that every mile on its course might be fairly irrigated. I may observe that the line runs between 29° 37′ and 26° 29′ north lat., and, as will be understood, is subject to the influences of local rain-falls and irregular demands for drawing off the supply, that lead to complicate a design which is otherwise sufficiently complicated.

Accepting Sir A. Cotton's views, that water can be taken from either the Ganges or the Jumna from any point of their course with the greatest facility, and that the nature of these rivers offers no impediment to drawing supplies from them, the difficulties attached to the problem are reduced to a minimum. *But there are grave reasons for denying Sir A. Cotton's views.* Experience is against them, and the most anxious observations made by myself and others tend to show that *the character of the beds of these rivers, below the shingle*

Digitized by Google

tracts, is opposed to them. I believe that, at the sacrifice of large tracts of valuable land in the valleys of the Hindun and West Kalli Nuddi, water might be collected in reservoirs for the purpose of giving a small additional supply at a point to the west of Meerut; but this would be gained by the very dangerous experiment of constructing permanent dams over the valleys of these rivers at an enormous cost, the sills, or wasteboards, of the dams being raised 15 and 25 feet respectively (see *Ganges Canal Report*, vol. i. p. 10). With this exception, *I am still of opinion that the Ganges Canal has no means of supply further than from the head above Hurdwar;* and I cannot, from Sir A. Cotton's speculations, and the conclusions arrived at from them, consider that he has weakened my views.

To the excess of slope in the bed of the main channel I refer with the greatest regret. The remedy, however, appears to be rather in the division of the great body of water, and thereby in diminishing the effects of its action, than in the continuance of the existing channel as a single line. From the head to Roorkee, in the presence and proximity of so much material, there can be no difficulty, I imagine, in putting the present channel in a perfect state of efficiency. From Roorkee to the Bolundshuhur head the volume of water might be divided so as to pass onwards in two independent channels, the one continuing on the line now in existence, the other in a westerly direction, or that marked by the Deobund Rajbuha: these two streams would unite at the Bolundshuhur head. The amount of volume passing down the two lines would be regulated by the requirements of the Futtyghur branch, and might on a general estimate be calculated at 3750 cubic feet per second for the eastern, and 3000 for the western. The bed of the eastern line would require to be protected, and the slopes to be remodelled. By an arrangement of this sort the capacities of the two channels would be brought to a manageable dimension, while it would offer the inestimable advantage of an alternative line for securing a supply of water to the southern divisions. From Bolundshuhur to Nanoon, the slope in the main channel, I presume, will require modification; and I should be

Digitized by Google

inclined to adopt the same expedient of dividing the volume of water either by the Bolundshuhur branch head, or by carrying lines of irrigation on each side of the main channel.

I am much in favour of *reducing the present volume of water in the main canal.* My belief is that the volume of water is too great for an artificial channel carried through a soil like that through which it passes below Roorkee. With so many falls, and with so large a body of water passing over them, perpetual repairs and interruption will inevitably occur, let the slope be reduced to any extent. *By the division of the waters this will be avoided;* and the evils of accident on one line will (as far as supplies for irrigation to the south are concerned) be neutralized by the existence of an alternative line.

I do not advert to Sir A. Cotton's schemes any further than to protest against—1. His dams and annicuts over the Jumna and Ganges below their shingle tracts.—2. His views of carrying the water of the main line of the canal above the level of the country. The first is visionary; and the second is quite unnecessary for the purposes of irrigation—in a sanitary point of view it is utterly destructive.

One word in conclusion: Sir A. Cotton's Report has forced upon me a reply, not for my own justification only, but as a duty to the Government whom I have served so long, and I have no hesitation in saying, so zealously. I have no affection for controversies, nor will I be drawn into them; here, as far as I am concerned, the matter drops.

It will be said that the Report is a private paper, drawn up for the use of the East India Irrigation Company, and not a public Report, deliberately submitted; as, however, it has been forwarded to the Government of India, and as by some means or other it has been printed, the Report is on the high road to become public.

Digitized by Google

V.

Observations by Major General Sir Arthur Cotton *on the foregoing Reply—No. 4.*

The circumstances which led to the writing of the Report to which Sir Proby Cautley replies, are stated in the short Memorandum, No. 3 of these papers, which Memorandum I wished to have been inserted in Sir Proby Cautley's Pamphlet. How my Report came to be printed I don't know, *as it was and is the property of the East India Irrigation Company,* and was shown to nobody but in confidence.

I cannot express the satisfaction I feel in the fact that, I have now an opportunity of meeting the objections that are made to my view of the present state of the Ganges Canal, and to the measures which I judge to be necessary not only to render that work, as now limited in extent, *reliably useful and profitable,* but to enable it to *irrigate a vast additional tract of country,* and thus improve the condition of a population of several millions.

The magnitude of the work under discussion, the brilliant auspices under which it was commenced, the enormous public benefits and highly productive returns which were predicted at the outset, and which for several years afterwards were universally expected to arise from its construction, have caused the failure *in money returns* which has hitherto resulted, to produce a correspondingly deep disappointment in the public mind, and—which is the great evil arising from the case—has created a general mistrust of the necessity for, and the value of, works of irrigation in India; so much so, indeed, as to form a serious impediment

Digitized by Google

in the way of their present or future advancement, either by Government or by private Companies. To dispel this mistrust—to show that it has no real foundation, but has been produced by error alone,—and to open up the way for, a clear understanding of the principles upon which works of irrigation and navigation in India can be made successful, is therefore of paramount importance to the prosperity of that country; and I am convinced that, this object cannot be more surely, or more promptly, effected than by a *free, full, and temperate discussion* of the causes which have led to the present unsatisfactory state of things, and the remedies which can with prudence be adopted. To assist in this remedial measure is entirely my object. I have not the least desire to impute blame to anyone, but simply to deal with a *public work* in a *public spirit*, and to show, by the light gained by long practical experience under a *successful system*, how that which at present fatally obstructs and prevents progress may be made the source of the greatest encouragement to, a successful and universal application of the waters of India to the fertilization of its soil, and the consequent bestowal of permanent, wide-spread blessings to its people. I must however add here, that, even as this work has been executed, the results in respect of money returns are shown in quite a false light by the Canal Accounts, as will be seen by the following extract from Col. Baird Smith's Famine Report:—"The officers "employed in settling the Land Revenue have invariably "asserted the right of Government to exact a higher "revenue than usual from estates benefiting by irrigation "from canals constructed solely at the public cost; they "refuse to recognise rights due to purely accidental vicinage "to canals. The users of canal water pay a small water-

Digitized by Google

" rate to the canal officers, and the revenue thus realized is " the only revenue which appears in the accounts of the " Irrigation Department. But it is *an utterly fallacious* " *idea of the true profits derived from the canals, inasmuch as* " *the Settlement Officer has absorbed into the Land Revenue a* " *large portion of the true Canal profits.*"

Colonel Baird Smith gives an example of 17 *estates*, in the Suharunpoor district, irrigated from the Eastern Jumna Canal, showing that the rents paid to the landowners had increased, from 1840 to 1860, from 16,000 rs. to 37,000 rs., in consequence of which the revenue officers proposed to increase the revenue, which in 1840 was settled at 11,600 rs., in 1860 to 16,200 rs., that is, by 4600 rs., while the increased rent had been 21,000 rs. Colonel Baird Smith's paper does not show what the extent of land irrigated in those estates was, but it is evident that this proposed increase of revenue (which is still not a fourth of the increase of rent) of 4600 rs., which appears to be the consequence of irrigation, does not appear at all in the Canal Accounts in its proper place as part of the canal profits. Col. Baird Smith does not give the area of irrigated land in those estates, nor the amount of water-rates, but by comparing this statement with others, I judge that the water-rate may have been about 9000 rs., in which case the proper canal profits, which only appear as part of the ordinary revenue, are about equal to those which actually appear in the Canal Accounts; and in that case the gross receipts of the canal are really double what the Canal Accounts give, and the nett profits considerably more than double. There is something extremely absurd in thus taking part of the canal profits in the form of canal dues and part in the form of land revenue, and thus falsifying

Digitized by Google

all the returns from irrigation, and leading to entirely false conclusions as to its remunerative effects, and consequently to the importance of extending it.

Sir Proby Cautley begins by endeavouring to show that there has been no remissness, on the part of the Government, in carrying out the works on the Ganges Canal; yet in a note (see p. 73) he mentions that, ground was first broken in 1842, and the works are not yet finished—*i. e., in* 1863, *or at the end of* 21 *years.* Everybody knows that, in England lines of railway that cost double what has been expended on the Ganges Canal, and which were began at the same time, have now been finished 17 or 18 years.

He next protests against my blaming the Medical Commission for the cutting of the canal entirely below the surface of the country; but in his Report of the 15th Sept., 1850, he says (par. 6), "There are three points that have greatly in-
"fluenced the designs of the works now estimated for, viz.:—

"1*st.—The results of the proceedings of a Medical Com-*
"*mission, which determined that the level of the high-water*
"*mark of the canal should be kept as much as possible below*
"*the level of the country.*"

By that Report, therefore, I was justified in attributing the deep cutting to the Medical Commission.

He proceeds to say that his project was especially for *irrigation,* and that *navigation* was entirely subordinate; that, nevertheless, strictures are passed as if it had been *mainly* designed for *navigation.*

To this I reply—

1st.—That I have nowhere supposed that it was *mainly* designed for *navigation.*

2nd.—The great expense incurred in *locks, &c.,* shows that *it was designed for navigation.*

Digitized by Google

3rd.—Col. Dickens, in his Report upon the Soane Canal Project, page 101, says—"It may be remembered, how-"ever, that notwithstanding the loud complaints which "have been made as to the excessive velocity of the current, "the want of headway in the bridges, and the want of "towpaths within the arches, the revenue from *navigation* "is the only branch of the revenue from the Ganges Canal "which *has already exceeded what the projector calculated* "*upon.*"

4th.—If it had not been designed for navigation as *a most important part of the project,* it would have been one of the greatest mistakes that could be made, because when such large irrigating canals are cut, they can be rendered navigable at a trifling additional cost, and thus an advantage obtained of the very first importance, to a country of great extent like India, so as to put the interior within reach of the markets of the world by lines of communication *of the cheapest and most suitable description.*

Sir Proby Cautley next remarks, that if I have had 35 years' employment on Irrigation Works, he has had 29. It is, on this account, of such importance to the State that we should now compare the results of our experience under two different systems, one of which has certainly been *eminently successful* in both the great leading points, viz., in *providing against drought,* and *in yielding great direct returns in money.* I however must add, and beg the reader to bear it in mind in going through these papers, that in one most important point, which essentially affects this discussion, the Bengal Engineers are absolutely without experience, while the Madras Corps have had the most extensive advantage in that respect, viz., *in building weirs across first-class rivers with sandy beds.* Neither Sir

Digitized by Google

Proby Cautley, nor any of the officer snow employed on the Ganges works, ever even *saw*, as I believe, a large weir.

A great portion of the Reply I am now remarking upon is based on this *entirely imaginary ground*, that weirs *cannot be built across a river having a Bed of Sand.* In all my communications with the officers connected with the canal, the line of argument runs in fact thus:—"*We have "never built weirs across large rivers with sandy beds, there-"fore, they never can be built.*" And this is also the main support of Sir Proby Cautley's reply. The argument of the Madras officers is:—"*We have built weirs across rivers of "from* 1000 *yards to* 4 *miles broad, with falls per mile of from "* 1 *foot up to* 10, *all having beds of nothing but unfathomable "loose sand, and the weirs, so constructed, have stood* 10, 20, "*and* 30 *years, and therefore the like can be done again.*" Which is the best logic? Surely even non-professional men can judge. There is indeed in Tanjore such a work *built by the natives in the second century, as is supposed, which is in use to this day.* There is something unaccountably curious in the way in which this point has been treated.

I have to speak upon this subject again presently, but I cannot leave it even temporarily without requesting special attention to its importance, as *upon the question of the practicability of erecting anicuts, or weirs, with perfect security across rivers having certain slopes and beds of sand, depends principally not only Sir Proby Cautley's defence of the Ganges Canal as originally planned, but the adaptability and value of the works recommended in my Report for its improvement and extension.* If the structures I have suggested are not only practicable, but economical and reliable, no Engineer, however wedded he may be to the system hitherto adopted in

Digitized by Google

the North-West Provinces, will, I am sure, deny, that they are exactly the works needed to remove a majority of the evils complained of, and to effect the objects desired.

Sir Proby Cautley then proceeds to remark on those points which I consider *fundamental mistakes in the original project.* The first is, *the position of the head of the canal.* He remarks that, I express my astonishment that, there is no discussion of this great point in the reports. Surely one might have expected that, in a report upon a great project, the reasons would have been assigned for this fundamental point, why the Canal was led off from a certain point of the river; especially when the point selected has evidently most serious objections. 1st. In its being such a great height above the country to be watered; and 2nd. In its being above a number of large jungle streams, the crossing of which involved an enormous expense. Who would not expect to find so great and important a matter as this discussed in the report of the project?

Sir Proby Cautley goes on to say that, I will be still more astonished when I learn "that all discussions, and "all experiments, have resulted in the inevitable conclu- "sion, that interference with the river in this part of its "course would end in utter failure. And that Colonel "Baird Smith, *who had seen our weirs in Madras,* fully "appreciated the difference between the engineering diffi- "culties of the Madras deltas and those of the high "lands of the North-West Provinces, and was quite satis- "fied that the projection of the lines of the latter, from "the *shingle, and not from the sandy beds, was the only* "*true and feasible one.*" Sir Proby Cautley supposes the slope of the river, below the confluence of the Solani, to be at the lowest estimate 1¼ *feet per mile;* it may be 2 or

Digitized by Google

3 feet at that point. Now, I ask, *what conceivable difference can there be between a river in the North-West Provinces with a sandy bed, and a fall of* 2 *or* 3 *feet in a mile, and a river in Madras with the same bed and the same fall?* And I will add, *facts not only show that there is no difference, but go further and prove more,* for, the upper anicut on the Cauvery is built *where there is nothing but sand, and a fall of* 3½ *feet a mile;* and the Pallaur Anicut where the *bed is also sand, and the fall about* 10 *feet a mile;* so that I am clearly entitled to say, the objection now dealt with is nothing more than pure imagination. *The work that would stand in Madras in a river with a certain bed and a certain slope would most assuredly stand in the North-West Provinces in a river with the same bed and the same slope.*

Sir Proby Cautley then says, that in 1827 an attempt was made to establish the head of the canal in the Jumna, and that it was abandoned after the first year's work. Of course, as so many such works have *actually since been built, and are now in use,* in exactly similar rivers, except that, they are much larger than the Jumna and Ganges are near the hills, there must have been an entire want of either knowledge of the subject or perseverance to go through with the work; and this was *thirty-six years ago.* Suppose men were to argue *now,* because men did not know how to construct first-class railways *thirty-six years ago,* therefore they couldn't be made *now*—the case is precisely the same. Probably this attempt was the merest nothing; but if it were ever so determined a one, what have we got to do with *a failure thirty-six years ago,* when we have had abundant and entire *successes* in all sorts of localities since?

Digitized by Google

If we are to act upon the failures of 36 years ago, rather than by the successes achieved since, we must not only give up these Anicuts and Railways, but also Ocean Steam Navigation, Enfield rifles, the Overland route, and some other things which would cause great inconvenience, for almost all the great modern improvements had either not been attempted, or had been failures 36 years ago.

Sir Proby Cautley then asserts that, *there is a vast difference between the Madras rivers and these—that is, the Ganges, &c.* To this I can only reply that I have seen both, and that *there is not the slightest difference, excepting that the Madras rivers are much larger.* We have now built eight Weirs of the first class, in rivers of all slopes, from 10 feet a mile downwards, with beds of *loose sand,* besides many smaller ones, and therefore I can speak with absolute certainty on this point, in repeating *that all the assertions that weirs can't be built on the Jumna and Ganges are based on nothing but pure imagination opposed to existing facts.*

Sir Proby Cautley then shows, where the irrigation would begin, if the canal had been led off at Sookurtal, below the confluence of the Solani, viz., about 90 miles below Hurdwar, or 70 below Roorkee, and that, the canal from this suggested new head would meet the present line of the main canal at a distance of *forty-five miles from Sookurtal* (see appended map); that is, that the new works required would be a weir at Sookurtal and *a canal of forty-five miles in length.* He then says that "it would not be the patch of land about "Roorkee to which the strictures refer, but the whole of the "Suharunpoor, Muzuffurnuggur, and the greater portions "of the Meerut districts, that would, by this plan, be "deprived of the benefit of irrigation;" and he adds, "So

Digitized by Google

" long as irrigation is given to a certain surface of the " country, it matters perhaps little to what country that " irrigation is given, but *as my intention was, and my project* " *was directed to, the irrigation of the above three districts,* it " appears rather hard that I should be found fault with for " endeavouring to effect it." To this I answer—1st. *I found no fault with Sir Proby Cautley; I was not making an attack upon him.* I was in the course of my duty giving my opinion, *privately, on the Ganges Canal works. There was no personal object whatever in my paper.*

2nd.—Does *intention* to make a mistake make the thing done no longer a mistake? The question here is not whether the mistake was *intentional* or not, but whether it was a *mistake.* My position is, that, to apply the water to *certain lands,* at an enormous expense, when there were lands immediately adjoining to which it could be applied at a much less cost, was a mistake. No reason is assigned for preferring those lands, and Sir Proby Cautley acknowledges that "*it matters little to what country the irrigation* " *is given.*" It is, therefore, evident that, without any reason, this great additional expense was incurred; this was certainly a mistake. Further, it must be observed that, taking the matter exactly as Sir Proby Cautley states it, viz., that the new head should be at Sookurtal, and that the water from there would reach the present main canal 70 miles below Roorkee, the tract of country above that point is only a small portion of the country commanded by the present head. The tract of country between Roorkee and the point on the canal near Meerut may be 1000 *square miles,* and only a portion of that could be watered, while the *remainder of the Doab, the whole of which could be*

Digitized by Google

irrigated, is about 18,000 *square miles,* about 10 millions of arable acres; and only about 1½ millions were intended to be irrigated, so that there was not the slightest necessity for bringing the water on a higher level than that. To show this more particularly:—In the original project of the Ganges Canal, 8 cubic feet per second were allowed for every mile of length, with the exception of the first 27½ miles, which were stated to be "*removed from the influence of irrigation*" (*Ganges Canal Report,* vol. iii. page 142), and therefore excluded. Each cubic foot per second was stated to supply water for 350 beegahs (or 220 acres), and the total supply was 6750 cubic feet per second, corresponding with the irrigation of 1½ *million acres.*

Sir Proby Cautley calculates that "if a cut were made "as proposed by me, it would be useful for irrigation *at the* "94*th mile from Hurdwar,* that is, *about* 51 *miles from its* "*own head,* supposing that to be at Sookurtal, 10 miles "below Badshahpoor; and that, had he followed that plan, "he would have been unable to provide for the irrigation "of, the whole of the Suharunpoor, Muzuffurnuggur, and "the greater portion of the Meerut districts."

It must be observed here that the *Eastern Jumna Canal* waters the north-west parts of the districts of Suharunpoor, Muzuffurnuggur, and Meerut,—about 850 villages. It was only the eastern parts of the districts that wanted water. If we compare the quantity of water actually provided for distribution throughout the above-mentioned 94 *miles,* we shall be able to judge of the *importance of the sacrifice made in comparison with the rest of the project.* Now, deducting from 94 the first 27½ miles not supplied at all, there remain 66½ miles, which, at the rate of 8 cubic

Digitized by Google

feet per mile, would distribute 532 cubic feet per second, and provide for about 120,000 *acres*, if there were so many which the water would reach, which number, compared with the whole acreage (1½ millions), and being *less than* 1-12*th*, *represents the proportionate amount of irrigation actually proposed to be supplied by the canal, as designed, to the upper districts in question.*

If we now compare the *actual sum allotted in the estimate*, as the expenditure upon the above-mentioned 94 *miles* with the corresponding cost of the lower 51 *miles*, which is the distance from Sookurtal to the 94*th mile*, at which Sir Proby Cautley states a cut from the river would be effective for irrigation, we shall readily perceive the *additional cost involved in drawing the immense volume of water from so great a distance unnecessarily*, for the sole object, as stated by Sir Proby Cautley, of watering the tracts in question in preference to an equal area lower down, which it is admitted could have been done according to my proposal.

The *estimated cost* of *the first* 24 *miles* was 575,000*l.*, and of *the next* 86 *miles* 305,000*l.* This section comes *down to the* 110*th mile;* and if we deduct the cost of 16 *out of the* 86 *miles* in order to arrive at *the expense up to the* 94*th mile*, we shall find that the whole *estimate* up to that point was *about* 823,000*l.*, perhaps *one million in actual cost;* and reckoning the 51 *miles* of the proposed new cut to cost, the same in proportion as the 86 above mentioned, it would amount to about 180,000*l.* Deducting this 180,000*l.* from the 823,000*l.*, the estimated cost of the works as carried out, we arrive at 643,000*l.* as *the estimated sum for the irrigation of the districts above mentioned*, the proportionate cost, in comparison with the estimate for watering all the other

Digitized by Google

tracts, being *little more than* 65,000*l.*, and the *actual additional outlay was probably near a million sterling.*

Lest, however, it should be objected that the cost of the annicut and head-works is not included in this calculation, it may be as well to mention, that those works still remain to be executed for the present scheme. The fatal consequences of omitting them have been already adverted to, and the attention of the Government of India was (as will be shown hereafter) pointedly drawn to the need of them by the late Col. Baird Smith, who proposed that an allowance of 100,000*l.* should be made for their cost; a sum which would be certainly amply sufficient to supply them at Sookurtal.

Again, supposing for some grave reason, not yet disclosed, it had been a *sine quâ non* to irrigate the comparatively small portion above the level just referred to, it was *the greatest mistake to bring the whole of the water intended to irrigate all the way down to Cawnpoor through the difficult country above Roorkee.* If it were an essential point to water a little over 100,000 acres above this level, it would only require a *small canal of about* 8 *yards broad and* 3 *deep, with a current of* 3000 *yards per hour,* to be brought from Hurdwar, *instead of one about* 56 *yards broad;* and thus five-sixths of the vast expense incurred in crossing the Solani, and other rivers, and in overcoming the great fall, would have been saved, and there would have been substituted for *five-sixths of this difficult* 94 *miles of canal* 51 *miles of plain cutting,* without crossing any heavy drainage at all. Sir Proby Cautley says, that from Sookurtal to the main canal near Meerut there would have been af all of 11 feet, while from Hurdwar there is a fall of 180 feet, so that *five-sixths of the works necessary to provide for a fall of* 169 *feet would have been saved, besides all the aqueducts,* &c.

Digitized by Google

He then adds that, the river below the confluence of the Solani has had its due share of attention from him. Upon this, I will only remark that, the fact proves the incalculable value of *experience* in projecting works of this character. No one will for a moment doubt that Sir Proby Cautley, gave his best attention and most zealous endeavours to fulfil the wishes of Government, and realize the utmost success; but from want of *experience*, and owing to *the strange delusion* (*it is really nothing else*) *that a weir cannot be built across a river with a sandy bed*, he was led into planning a work not only involving an useless expense of the greater part of a million of money, but incapable, on its completion, of satisfactorily fulfilling its intended objects.

Sir Proby Cautley next answers my objection about *the deep cutting for the canal*, and first makes some remarks about my observing upon one effect of this, viz., the water being below the level for irrigation, and then shows how the water is distributed so as to bring it out on the surface of the land without raising it. It is quite true that, in this way, most of the water is delivered at a sufficient level, but it is also true that, *the arrangement is imperfect*, because in the returns the irrigated lands are divided into two classes, Dal and Tor—*i.e.*, those irrigated *by means of machinery to raise the water to their level*, and those irrigated *direct* from the canals, showing that it is only part of the irrigation which is supplied without additional means and additional expense to the cultivators.

However, this is a small matter compared with the other point, *the enormous cost of excavation, and the enormous loss of time* in consequence of the *whole* of the water being carried *below the level of the ground.*

Digitized by Google

The actual section may be taken, on an average, at about 56 yards by 4, or 224 square yards, for the conveyance of 850,000 cubic yards per hour, intended to be filled to about 10 feet, with a current of about 5000 yards, or 3 miles per hour. Now, if it had not been determined, to carry the *whole* of the water *below the surface*, all the excavation that would be required would be only enough to make two embankments, which might have been put any distance apart. Thus, the embankments might have been 2 yards high by 5 broad at top, or about 20 square yards each, or together 40 square yards, or $\frac{1}{6}$ of the actual excavation. The water would then have been 6 feet deep, *three-fourths above the surface* of the ground and *one fourth below*, and the distance between the banks or breadth of the excavation about 80 yards. Thus, this mode of proceeding would have *saved perhaps* $\frac{3}{4}$ *of the excavation and* $\frac{3}{4}$ *of the cost*, and, what is of vast importance, it would in consequence have allowed of the work being done *in* $\frac{1}{4}$ *of the time*, so that the works would have been in operation and making returns many years ago.

I had said that, by cutting so deep they had exactly produced the effect that it was intended should be prevented, viz., percolation, by which the water would keep the surface of the country wet and produce fever, for *the upper stratum, only for a few feet, is water-tight, and below it is all loose sand.*

Sir Proby Cautley says that, if the excavation had been shallow it would not have prevented percolation, because *in some parts* the sand is at the surface. It is remarkable that this fact about the thin stratum of water-tight soil and the effect of cutting through it was first brought to my notice, some years ago, by Colonel Baird Smith, as the general state of the country through which the canal runs. Sir

Digitized by Google

Proby Cautley's statement that *in some places* there is a *sandy surface* cannot, of course, the least affect the question. *That there is a small portion of the line where the surface is not water-tight can't be a reason for cutting through such a stratum where it does exist, which is almost throughout the whole length of the canal.*

But the reason assigned for cutting the canal deep was to *prevent the leakage.* Nothing can be more evident than that to cut through the water-tight stratum *was the very way to produce it,* and *has* produced it. The loss is stated to be about 60,000 cubic yards per hour in 50 *miles only* between the head and Jaoli, the head of the Futtyghur branch, all of which finds its way *through the sands and keeps the surface of the country wet with stagnant water in places,* the supposed cause of the fever—*the very effect that the Medical Committee intended to prevent.* Now, had the water been allowed to stand one yard *above the surface,* retained by *banks of water-tight earth,* 2 yards high and 15 yards thick at the bottom, there would have been no leakage; the depth, and consequently *the current, might have been diminished,* $\frac{3}{4}$*ths of the excavation saved, and consequently* $\frac{3}{4}$*ths of the time, and the distribution of the water simplified.*

The sad effects which a continuance of the present percolation may have upon the long strip of contiguous land is a question which *must* be taken up remedially by the Government; it *cannot* be avoided.

Sir Proby Cautley next answers my objection to *the sole use of brick when excellent stone was to be had close to Hurdwar.* He first says that he does not object so much to brick masonry as I do, yet adds, "*No man in his senses would "select brick when good stone is to be had at a reasonable "price.*"

Digitized by Google

I did not object to brick masonry *generally*, but only *where it has to bear heavy falls, or velocities of water, as over weirs, or through sluices.* I consider that brick answers all the purposes of stone in other situations, and especially such beautiful brickwork as these works are composed of, and which is certainly equal to any I ever saw. In *general* I would only use stone where it was as cheap, or where, on any account, it was difficult to make bricks in sufficient quantities. Sir Proby Cautley's principal defence of the bricks is, that the stone was very variable in quality. It generally is so where sandstone occurs in India. It was so at the Godavery works; there was stone of every degree of hardness. We, consequently, had to select the hard stone for particular parts, and were often obliged, in order to save time, to put in softer stone than was desirable; but harder stones have since been substituted for soft ones at the officer's leisure. But still all that was used was incomparably safer than brick. That there was most excellent stone, perfectly fitted for the works on the spot, is certain, for I saw large blocks of it lying in the streets of Hurdwar, intended apparently for some building, and which I was informed *had been brought only* 6 *miles.* I have pieces of this stone with me now.

Sir Proby Cautley then, quotes from a Report of the officers on the spot on *another kind of stone,* a hard conglomerate, which was found 10 miles off, and which they objected to because it would cost 27 shillings a cubic yard. I don't suppose it would cost so much as that; but if it did, it would be no obstacle to its use. Such stone would only be required to cover the apron of a weir on which the water falls. To show the cost of this material in a weir across the Ganges at Hurdwar, suppose the weir was 500 yards

Digitized by Google

long, and the apron 15 yards broad, and the stone covering 2 feet thick, it would require 5000 cubic yards, costing at 27 shillings, or 13½ rs. per cubic yard, under £7000; or even if 1000 yards long, the cost would only be £14,000—a very moderate sum in such a work. To judge of these lengths, the Godavery Anicut discharges 50,000 cubic yards per hour, for every yard in length, and the Kistnah Anicut 120,000 cubic yards. The quantity to be discharged at Hurdwar is, I believe, 25 million cubic yards, so that even 500 yards length would only give 50,000 cubic yards per yard of length, the same as the Godavery.

It is an undoubted fact that the brick weirs have failed, and have obliged the officers to shut the canal in the midst of the irrigating season. When I was there, they (the weirs) were in such a critical state that the officers were entirely at a loss what to do about them, and *I insist upon it that, this is solely because they are built of brick.* We have certainly had failures with our weirs in Madras, though covered with stone, but there are hundreds now in use that have stood 20 or 30, or 40 years, and that never cause one moment's anxiety.

Sir Proby Cautley also remarks that, I am mistaken in supposing that, the river pebbles have not been made use of; but it is certain that, *the great mass of the masonry is of brick.* He also says, these pebbles were used in some of the works; but it must have been a very small proportion, for I saw no pebble masonry, nor was it ever mentioned or alluded to in the long discussions I had with the officers on the spot.

Sir Proby Cautley mentions that, there are large masses of old pebble masonry at Badshahmuhal. It seems very strange that, with such a hint, they were not generally used

Digitized by Google

when there were unlimited supplies on the spot. He then concludes this part thus:—"The implication that every "useful material has been rejected and neglected by me in "the construction of the works is, to say the least of it, "not very *complimentary*." But it is obvious I was *neither complimenting nor finding fault* with any person, but merely *reporting facts in a private paper to my employers, with my professional opinions on them, for their information.* These facts were simple and undeniable, viz., that the officers were entirely at a loss, from the failure of the brick works, while there was on the spot excellent stone, which I saw and examined in company with the officers of the works. *My professional opinion was and is, that had this stone been used in those works, there would not have been the smallest anxiety about them.*

Sir Proby Cautley next replies, to my remarks *on the conveyance of the whole of the water from the head at Hurdwar by canal, so that some of it was brought at an enormous expense,* 350 *miles,* by asserting, that if he had admitted water 250 miles below Hurdwar, the whole of the lands above that point would have been thrown out. But he has mistaken me; my words were:—"*The fourth mistake is, "that* THE WHOLE *of the water is admitted at the head (Hurdwar);*" (see p.), and further on (see p.)—"*Probably one or two "such* ADDITIONAL *heads from each of the rivers Ganges and "Jumna might be cut with advantage.*" I did not propose that *no water* should be admitted higher up. What I proposed was that, *instead of cutting an enormous channel to convey the whole of the water from Hurdwar, involving a vast expense, I would have made use of the river channels to convey, a large portion of it, as far as the levels would admit.*

Supposing the whole of the canal excavated to carry the

Digitized by Google

water below the surface of the ground, and that the current is 4000 yards an hour, it is evident, that to bring 4000 cubic yards of water 250 miles, there must be excavated 250 × 1760 × about $1\frac{1}{4}$ yards, or 350,000 cubic yards, costing about 55,000 rs.; and allowing $\frac{1}{2}$ a cubic yard of water per hour to the acre, we have 8,000 acres watered for a capital in excavation alone of £5500, or about 14*s.* per acre; or supposing half a million acres are watered below the 250 miles from Hurdwar, it would cost for excavation alone £350,000, besides the portion of the cost of the masonry, weirs, &c., perhaps in all half a million sterling. What I mean to say is, that *it would have been far cheaper to have made a second weir across the Ganges, with a new head canal of* 28 *miles* (*or* 50 *miles*), *than thus to bring the whole of the water from Hurdwar.* I hope this will be intelligible. I did not propose to irrigate an *entirely new tract of country*, but merely to urge that if the land about Cawnpoor is to be watered, as it is by Sir Proby Cautley's project, there would be an enormous saving in making use of the river to convey the water most of the way, instead of conveying it 250 miles by an excavated channel. The question is surely a very simple one, and capable of a very easy solution—it is, *Which would be cheapest? to bring the water from Hurdwar, or from a point only a hundred miles above Cawnpoor*, though the latter would involve a second weir and head canal? But then, this additional weir would afford the further vast advantage of turning on to the land all the water that falls into the river or drains out of the sands between Hurdwar and the site of such weir, probably 300,000 or 400,000 cubic yards an hour, or sufficient for $\frac{1}{2}$ or $\frac{3}{4}$ million acres. *This alone would justify the cost of the weir several times over.* Sir Proby Cautley, in his pub-

Digitized by Google

lished account of the works, says, that at 95 miles only below Hurdwar there was an addition of 1500 cubic feet a second (nearly 200,000 cubic yards an hour); and we may be sure that 150 miles still further down there was a great addition to this.

Sir Proby Cautley then replies to my objection that *there was no permanent weir at the head of the canal.* He says that his principal reason for not constructing one was that *the temporary expedients had been found to answer on the Jumna.* There is certainly some real argument here. *Results have, however, shown that it was a mistake,* for the officers failed to keep up the supply by such means at a most critical time, and just when that supply was most wanted, viz., in a year of scarcity. Thus, I find in September, 1861, the supply in the channel was only 2900 cubic feet per second, half what it ought to be, about 350,000 cubic yards per hour, while in other months it was 700,000 cubic yards, and in October, 1859, it was only 950 cubic feet per second, 120,000 cubic yards per hour, 1-6*th of what it might have been.* In Colonel Baird Smith's Report on the Famine, dated August, 1861, hequotes (par. 109) from the Superintendent-General of Irrigation as follows:—

"In the beginning of September the volume of the Ganges "began rapidly to decrease, and by the end of the month "the supply of the canal was nearly 1-3rd short of that "required for effective irrigation. Uncertain as we were "whether the last floods of the season, often among the "heaviest, were over, we felt a natural reluctance to com- "mence the repairs of the costly bunds or temporary weirs "at the head of the canal, and thus the canal was unable to "meet the unusual demand for water which arose at the "close of the Khurreef (autumn) season. Before the middle

Digitized by Google

"of November, however, the head-works were restored, and "during the remainder of the spring (Rubbee) crop the "canal was efficiently supplied." That is, that at the very time for which, above all others, the works were constructed, a time of famine, from the beginning of September to the middle of November, *solely on account of the want of permanent and reliable works at the head,* there was a most terrible deficiency of water in the canal; and the deficiency actually began before the time here mentioned, for it was very *early* in August. The average for the four months, August to November, was just 4000 cubic feet per second, or half a million cubic yards per hour, while in December the supply was 5800 cubic feet, or 725,000 cubic yards per hour, *not from any want of water in the river, but solely from the want of a reliable head weir.* This average deficiency of 1800 cubic feet, or 225,000 cubic yards per hour for four months, amounts to 320 million cubic yards; enough, at 1200 cubic yards per crop, for more than ¼ of a million of acres, the value of which, in money only, would have been, at that time, according to Colonel Turnbull's estimate of the value of the crop, on an average about 45 rupees per acre (150 lacs for 340,000 acres), more than a million sterling, or *in a single season twenty-five times as much as a weir would probably have cost.* Colonel Baird Smith again says (see his Report, August 14, 1861, par. 109):—"The actual "effects of the Ganges Canal during '60-61 are most "inadequate measures of its prospective influence. *During "two successive seasons, one of scarcity of moisture, the other of "absolute drought, the head works of the canal have failed to "insure supplies of water at the most critical periods of the au-"tumn crops.*"—I think it must be allowed that after spending two millions to run such a risk of a defective supply at

Digitized by Google

most critical times for want of an expenditure of probably 40 or 50,000*l.* (or even of 100,000*l.*) is now shown to be a mistake. I must again say that *I am not judging the projector, but the project.* I am not saying that the *projector* made a mistake, but that there is *a mistake in the project.* Under the circumstances of the case, and with the less knowledge of such things that there was twenty years ago, the projector may have been right in not constructing a *permanent* weir, but this is not our present question; that question is, With the light thrown on the subject by the past history of these works themselves, and by the history of the numerous great hydraulic works that have been constructed in Madras before and since that time, what serious mistakes do we discover in these works, and how can they be corrected? The two great facts are as plain as possible:—1st. *That the want of a reliable head weir is a most terrible defect;* and 2nd. *That from what has been done in so many similar situations, we know that such a work can be constructed at a cost altogether trifling compared with the value of even the property at stake, to say nothing of the lives, &c.*

It is stated that 2000*l.* a year is now spent on the *temporary* works, that is, the interest of a sum four times as great as the Godavery and Kistnah Annicut cost, in proportion to the volume of water to be controlled; so that in fact the weir will cost nothing. I may mention here, that thirty years ago we came to this conclusion with respect to the supply of Tanjore from the Cauvery; the natives, from want of our great means, had been in the habit of obtaining an uncertain supply of water by means of such temporary dams, but we had had abundant proofs there also—similar to those in the case of the Doab—that to trust such tremendous interest, as the lives of millions of

Digitized by Google

people, to such uncertain and precarious works, when great additional security could be obtained at an insignificant cost, was a mistake, and in 1836 we constructed two weirs, one where there was *a fall of* 3½ *feet a mile,* and the other where it was 2 *feet* (the lowest probably equal to the fall at the mouth of the Solani), *with beds of loose sand;* and though we made mistakes in their construction, and had accidents with them, yet they were both, from the very first, perfectly effective, and nothing can be more satisfactory than the results. The revenue of Tanjore alone (two other districts were affected) has been increased nearly half since then, an additional revenue of nearly 700,000*l.* a year, and there is no question but that the foundation of all that improvement was those permanent weirs. They cost about 10,000*l.* each at first, but have been greatly improved since. They, however, were both in effective operation in three months from the time they were begun, and *have never failed during these* 27 *years.* In now planning works for the Ganges we should have the vast advantage of these 27 years' experience with these works; and with so many other and still larger ones, surely we need not be afraid to attempt similar works on the Ganges.

Upon the above two works in Tanjore depend almost entirely the well-being of more than 2 millions of people, a revenue of about ¾ million sterling, and an annual crop of the value of 3 or 4 millions, and they cost in all 30,000 or 40,000*l.* How insignificant such an expenditure compared with the interest at stake, even in money only. And we must add to this that, all the surrounding districts have been in a great measure preserved from famine repeatedly by the crops secured by these works. Just the same is the case with the Ganges. The well-being of millions, and crops of the value

Digitized by Google

of millions sterling are waiting for works to cost 30,000 or 40,000*l.*, or say 100,000*l.* The revenue to be derived from water-rate alone upon 1½ million acres will be about a ¼ of a million sterling.

On this point we have seen that Col. Baird Smith, notwithstanding that, he was *somewhat affected by the Bengal fancies about the difficulty of constructing weirs in sandy rivers*, was quite decided in insisting upon the grievous mistake of leaving such works dependent upon such *precarious* means of supply, and in urging upon Government the construction of a *permanent* weir. He says again, in par. 126 of his Famine Report, "It is evident, however, "that such development" (the completion of the works so as to secure the whole Doab) "will be very imperfect so "long as one harvest of each year is exposed to the casual- "ties of the autumn crops of 1859 and 1860, by reason "of the defective control over the river supply. *The "establishment of an easy and certain command over that "supply is essential to the efficiency of the canal as a pro- "tective agent.* It was with the view of making myself "acquainted with the design for this object, that, in com- "pany with Col. Merton, &c., I visited the head works in "June last, &c. I have no doubt that the general scheme "will prove practicable, and that its cost will not exceed "the limits reasonably allowable in securing so great an "object, &c. The works as projected are not likely to cost "more than £100,000"—*i.e.*, ten times as much, in proportion to the volume of water, as both the Kistnah and Godavery works had cost. There is certainly no reason for such a great disproportion of cost in the two localities. In fact, in one important point, there is a very great advantage in this site over either of the others, viz., in the

Digitized by Google

unlimited supply of both loose stone and hydraulic lime over the whole bed of the river at the very spot, while all our materials had to be quarried and brought from the hills from a ½ to 5 miles distant. He continues—"The "actual estimate is considerably below this, but the work "is difficult, and the contingencies are many. The agri- "cultural property dependent upon the canal will rise in "time if the agricultural community can *rely implicitly* on "the virtual *certainty* of the supply to full six millions "(sterling). The true state of the case seems to be *that* "*without this expenditure, be it moderate or immoderate, the* "*whole action of the canal will be imperfect, the confidence of* "*the people in its protective powers cannot be complete, and* "*in every season of extraordinary aridity the supply will fail,* "*just when water is most precious.* Under these conditions, "I feel no hesitation in respectfully requesting the favour- "able consideration of the Government of India to the "project of permanent *head works.*" In this paper we find not a word about the *impracticability* of the works. Doubtless Col. Baird Smith's, actual inspection of several weirs in Madras, had forced him to believe that, such works were *practicable;* and no doubt the main reason why he did not construct a weir was (what Sir Proby Cautley states), his idea that a *weir was a very difficult work.* Sir Proby Cautley afterwards repeats that *my experience is with rivers of an entirely different description.* But there is not a shadow of ground for this assertion, as I have before stated.

At page 7 Sir P. Cautley says, "The projection of "the lines of the latter (the canals in the North-West "Provinces) *from the shingle and not from the sandy tracts,* "*was the only true and feasible one.*" Then, again, he says—"*Here* (*i.e.*, in the North-West Provinces) we have

Digitized by Google

"heavy slopes with large masses of water pouring down "with overwhelming violence; *there* (in Madras) he has "much larger bodies of water, but on *very much smaller* "*slopes.*" The difficulties here supposed are, I again assert, all *imaginary;* but if they were real, we have not only had a heavy slope, as at Hurdwar, and sand with a moderate slope, as at the mouth of the Solani, but *both combined in sand with a heavy slope of about* 10 *feet a mile in the case of the weir on the Pallaur.*

Sir Proby Cautley still dwells upon this point, as people always are more afraid of Ghosts than Realities, and says, "*This slope makes all the difference.*" I must assure him, from *actual experience,* that it makes *no important difference;* that we have had no particular difficulty in establishing a weir where the slope was as great as at Hurdwar; and further, that not one additional precaution was necessary on the *Pallaur* where the slope is much greater. I do feel sure that I may fairly propose my experience, after having been more or less concerned in the planning and construction of seven or eight of these great weirs, against that of officers who not only never built one, but never saw one. *I am quite sure that the Ganges will as quietly submit to discipline, of the nature proposed, as the Cauvery, the Coleroon, the Pallaur, the Pennair, the Kistnah, the Godavery, &c.*

Sir Proby Cautley thinks that, I am wrong in supposing the weir at Hurdwar would cost only 30,000*l.* or 40,000*l.*, and that it would cost, as estimated by officers on the spot, nearly double that sum, and very much more if stone is used. My data are the Godavery Annicut, 12 feet high, which cost about 200 rs. a yard in length, and the Kistnah, 16 feet high, which cost about 500 rs. a yard, and each of them about 4000 rs. per million cubic yards of discharge

Digitized by Google

per hour. At this rate, the Hurdwar Weir would cost, for 25 million cubic yards, 10,000*l.* only; and there is no reason that I can see why it should cost more than three or four times as much as those on the Godavery and Kistnah. I have shown before, that, even at the very high prices allowed by the local officers, the cost of stone for the apron would be no excessive portion of the cost.

I may as well introduce here another extract from Col. Baird Smith on the subject of making the head of the canal below the Solani (par. 123) :—"From 50 to 70 feet repre- "sent the general depth of the great rivers below the surface "level of the country, and from 1½ to 6 miles represent the "width of the troughs or valleys in which they flow. "Under these conditions, the prospect of making more "of these rivers than has already been made is not "encouraging; *at the same time the question has never been "systematically examined.* The information available is "fragmentary and incomplete. Using it as well as I could, "I have come to the conclusion at present that no works "directed to the delivering of the water on the high lands "of the Doab from any points on the Ganges or Jumna "more than 12 or 15 miles below their respective places of "departure from the mountains are likely to be financially "practicable. *Physically practicable of course they are,* but "dams of such magnitude would be required to cross the "rivers, and channels of such depth through the high "lands, that the cost would counterbalance the gain so "greatly that it would probably be idle to think of "executing them. *But I would gladly see the matter sub- "mitted to intelligent examination, as it may be that, the "imperfection of our present knowledge has led to narrower "views being taken of the question than are right.*" My

Digitized by Google

remarks on this passage from Col. Baird Smith—one of the Ganges Canal Engineers—are—

1st.—That, it is quite certain from it that, he did not think that the river had been *properly* examined below the Solani.

2nd.—That he had at least a strong suspicion that it might be economical to lead the water from that part of the river. He positively says, "Physically practicable of course they are."

3rd. What can he mean by "dams of such magnitude" and "channels of such depths through the high lands" would cost so much that it would be idle to think of executing them? He himself had seen the dams across the Godavery, Kistnah, and Coleroon; the smallest of them larger than one would be at the mouth of the Solani, and the largest of them across a river of eight times the width and about six times the volume of the Ganges there. And for the channels he says the height of the ground is from 50 to 70 feet, so that with a fall in the country of 3 feet a mile, a channel of 20 or 30 miles long would, without any cutting through high land, lead out the water upon the plain. And, even taking Sir Proby Cautley's statement, a channel 51 miles long (across a tract without a single river or other obstacle) would lead the water to the high ground near Meerut, *to reach which same point there has actually been cut a canal of* 90 *miles from Hurdwar,* 20 *miles of it across several rivers; the passage of one of which cost* 300,000*l.*, *and the whole* 90 *miles I suppose about one million, while the canal from the mouth of the Solani probably would not cost more than* 3000*l. a mile, or* 153,000*l. for the* 51 *miles.* Surely this view of the matter is straining at a gnat and swallowing a camel.

Compare the work now advocated with what is now nearly

Digitized by Google

accomplished by the Madras Irrigation Company on the Toombuddra River at Kurnool, which river is there about *one hundred and fifty feet* below the water-shed immediately south of the confluence of the Toombuddra and Kistnah. The Company have constructed an annicut or weir more than 1¼ miles in length across the river, and they have also nearly completed a canal to carry 400,000 *cubic yards per hour* (3200 *cubic feet per second)* for 72 miles through a very difficult, rocky, and undulating country, including a stone aqueduct across the Hindry River of 300 yards' length, crossing also several small streams, besides a considerable rocky cutting through the water-shed itself; and the whole of this will have cost, I believe, about 200,000*l.*, or say 250,000*l.*

Further on, in the Report I last referred to, in speaking of the Sutlej River, Colonel Baird Smith proposes this very plan of drawing off its water *at points far from the hills.* He says, "It is not at all necessary to suppose that, a canal "from the Sutlej at a high level will exhaust the capabilities "of that river for agricultural purposes. Such a canal "would be the first and best use of the waters, but hereafter "it may be both expedient and practicable to draw other "lines from lower levels, which, though not efficient nor "so reliable in their action, may still become very valuable "and give additional guarantees for the security of that "tract."

I need not answer Sir Proby Cautley's remarks on what I call *minor mistakes* so much in detail as I have his others.

On the 1st, *the length of the falls,* I admit there is something in his argument that they were made so long partly to allow of a portion being shut up in case of injury. I have had sufficient experience of water not to despise any precaution against the enemy. *But even allowing for this,*

Digitized by Google

they might have been made of two-thirds their present length. I must however repeat that we have such multitudes of such works *standing perfectly, when covered with stone,* that I do not think it necessary to go to such an expense to provide against accident in this way.

Sir Proby Cautley does not reply to my other objection to the *height of these weirs,* viz., that they caused a much greater fall to the surface of the stream than he had given to the bed, causing a most severe current for some distance above them. At page 25 he mentions the dangerous expedient to which this had driven the officers, viz., that of raising these brick works by timberwork, and thereby exposing them to a still greater force of water than they were intended to bear, and justly says, "*This remedy, while averting one danger, has given birth to another not less serious.*"

On the 3rd minor mistake, *the great slope of the canal,* Sir Proby Cautley remarks that, it ought to have been placed at the head of my fundamental ones, and thinks it is the cause of the injury to the masonry falls, but *I do not think that, nor at all that "it has been the cause of all the disasters that have occurred."*

Under the same head Sir Proby Cautley says, further on, "I see no remark in Sir A. Cotton's report tending to "show that he looked upon them (the large masses of "water) as affecting the project; so far from it that he "proposes a depth of 18 feet without the slightest hesitation, "and without the most distant idea of having any difficulty "in dealing with it." Sir P. Cautley is right. *I have not the slightest hesitation upon the matter, or the most distant idea of any difficulty* in dealing with such masses of water as are required to be controlled in order to place the Ganges Canal in its proper state, or to ensure its full extent of

Digitized by Google

usefulness. And *from experience* I have gathered this important lesson, that there really is no particular difficulty in dealing with such a depth of water. Are the railway engineers very presumptuous when they now propose to deal with velocities of 10 or 20 miles an hour? The only thing is, that to *retain the same current if the depth is greater, the slope of the bed must be less.* If we allow a current of 3000 yards for a depth of 9 feet, the slope must be 6 inches; if we have a depth of 18 feet, it must be 3 inches; that is all the difference. *In the Godavery we had to deal with a depth of* 30 *feet, and* 18 *feet passes over the annicut. In the Kistnah we have a depth of about* 37 *feet, and more than* 20 *feet over the annicut.* Sir Proby Cautley then, again, attributes the failure of the weirs to *the slope of the bed of the canal.* In my opinion *it does not make the slightest difference.* I feel sure that if these brick weirs had been waste weirs in the bund of a tank, they would have had just the same force of water, and would have failed. He says also, "I look to the "improved plan of falls adopted in the Baree Doab canals "rather than to the weak projections of Sir A. Cotton." How very odd it seems that he should speak of these weirs as if they were some new idea of an inexperienced man. They are no present invention of mine, but such works as have been built by hundreds in Madras, in every possible soil and position, and *have stood perfectly, some of them* 40 *or* 50 *years.* To think such works *weak projections* is surely a mistake, when they have given such ample proof of their being *abundantly strong.*

On the non-extension of the canal from Cawnpoor to Allahabad, Sir Proby Cautley says that his project was for *irrigation as far as Cawnpoor.* What I urge is, that *this was a mistake in the project.* 1st. The abstraction of

Digitized by Google

water from the river would greatly injure the navigation by that line; and this evil was of such vast importance as to go far to counterbalance the benefit of the *irrigation*. Nothing can be stronger than the testimony of Col. Baird Smith and others to the excessive pressure of the demand upon the water-lines for the conveyance of food to the famine districts in 1860-61. He says, "In 1860-61 the "total importation of food-grain (by all means of con- "veyance), amounted to nearly 5 million maunds (180,000 "tons). There is nothing extravagant in supposing that "15 or 20 million maunds ($\frac{1}{2}$ or $\frac{3}{4}$ million tons) may, "when the system of communication is perfected, be thrown "into any part of this region between the two harvests. And at par. 173, "It is scarcely to be expected that our "existing canals of irrigation will ever be very perfect "channels of communication. But that, they may be made "of considerable use has been clearly shown by the extraor- "dinary increase of traffic on the Ganges Canal during the "famine period. The number of boats increased from less "than 200 to about 1000 between January and June, "1861, and they were still below the demand." He then recommends *a separate line of canal for navigation*, and after speaking of railways, adds, "I am sure that even "when such means of transit are fully employed with re- "munerative returns, there will yet remain a great mass "of produce for which cheap water carriage will be *a* "*necessity*." And Col. Turnbull says, in his Report for 1860-61, "The demand for new boats was so great during "this period that they could not be built fast enough to "meet it; and so high was the value of a boat on the "canal that, notwithstanding the most extravagant prices "given for it, anyhow put together, and of the most

Digitized by Google

" temporary materials, one month's working nearly repaid " the cost, and the second gave a profit."

To give *an idea of the extreme value of water for navigation at such a time,* supposing that a lock of 150 × 20 feet will admit a boat of 300 tons, the consumption of water in passing would be about 1000 cubic yards, less than that required for an acre of wheat, which would not produce one ton of food. The fact is, that great as is the value of water for irrigation, it is, at such a time, immeasurably greater in placing at the disposal of the people, so afflicted the supplies from distant districts. The quantity of water consumed in navigation is so trifling that it would be almost imperceptible even at such a time. At the above rate of 1000 cubic yards for 300 tons, it would be only a little more than 3 million cubic yards for a million tons, sufficient for 4 million persons for a year, while the quantity of water brought by the canal in a year, at a million cubic yards per hour, would be 9000 millions, so that 1-3000th part of the water would provide for the conveyance of food to 4 millions of people. With respect to Col. Baird Smith's doubts that the irrigation canals will ever be very effective navigations, I have only the same to say as I have said about weirs; that it is only *a pure fancy, without a fact to support it, and utterly overthrown by the actual effective working of the Rajahmundry canals for* 12 *years.* The whole traffic of the district is carried on by these canals at prices much below the lowest on railways, and yet with excessive profits to the boat-owners, notwithstanding that the boats are absurdly unsuited to canal traffic, and worked at fully five times the expense that good canal boats could be worked at.

Col. Baird Smith again says (Report, May 8, 1861,

Digitized by Google

par. 20)—"So miserable are the means of intercommuni-
"cation in many of those districts of supply, that while
"in one *bazaar* famine prices of 4 rs. a maund (11*l.* 4*s.* a
"ton) might be ruling, in another, not 30 miles off, the
"price would be but 1½ rs. a maund (4*l.* 4*s.* a ton)"—a difference of 7*l.* a ton, while the cost of carriage by water would have been, at ⅛*d.* a ton per mile, 4*d.* "Though "its navigation is precarious, the Jumna was the channel "of a considerable flow upwards to Agra from Allahabad." "The Ganges was but little used by reason of the low "level of its waters; small supplies were however brought "up by it to Cawnpoor." (Par. 28.) "The noticeable de-
"crease in the volumes of the Ganges and Jumna has sen-
"sibly affected the trade in those rivers." "In December,
"1860, indeed in February, when I had an opportunity of
"seeing the rivers, they had almost ceased to be means of
"communication at all." "Few causes act more directly
"on the free spread of Manchester goods than communi-
"cations of any kind. It is along the best of these that
"English cloths have most largely commended themselves
"to the people, and the interests of the manufacturing dis-
"tricts of England is most direct and personal, in the state
"of the roads and rivers of India." (Par. 31.) "The chief
"consumers of English cloths here are all classes near, to
"open and easy lines of communication, be they by land or
"water, with a comparatively small section of agriculturists,
"being the upper grades of the class at a distance from such
"communications." (Par. 20.) "And even if our hopes
"of a favourable rainy season should be disappointed, the
"practicable question will then be, not so much how to
"get food as how to get the starving people to the food,
"or the food to the starving people."

Digitized by Google

When navigation was of such prodigious importance it was certainly a mistake not to continue the canal down to Allahabad, especially as the river navigation was to be seriously injured by the abstraction of the whole stream at Hurdwar, and when it could be done at so small a cost.

Sir Proby Cautley continues upon this point in the next paragraph, where he says, "It is only when the demands for "irrigation are small *that water runs to waste in the river.*" And again in page 38, he says, that when the supply of water is limited, as it is on the Ganges Canal, especially "at a distance of 360 miles from its source of supply, if "navigation is to be insisted on, it will be at sacrifice of "irrigation." I really don't know how to make this case plainer than I have already. It is so extremely simple that much explanation only seems to me to make it dark. *From the point in the canal where the last irrigating channel is led off, no matter where that may be, or how near to the terminus, the water is retained on a dead level to the end. No water, or rather only the inappreciable quantity used for lockage*—the whole intended for irrigation may be so used —*then runs to waste.* It seems to me that no multiplication of words can make this plainer. *This is the plan in all the canals in Rajahmundry.* The few miles between the last branch and the lock which connects the canal with the river are level, *and every drop of the water is used for irrigation,* excepting the lockage water, which, as I have shown above, is perfectly insignificant.

Leaving Sir Proby Cautley's reply for one moment, I am led by the nature of the point just discussed to observe that, of the absolute *necessity* of water carriage we have the strongest possible proof in Captain Haig's Report on the American River Navigations. That officer was sent by the

Digitized by Google

Secretary of State to examine the inland navigations of the United States, and I take the following information from his published Report: — On the Hudson about 3,000,000 tons were carried per annum, and this during the time the canals were not closed by frost, and 35,000 tons were carried through by land, between New York and Albany; so that 99 per cent. was carried by water, and little more than 1 per cent. by land. Again, in Cincinnatti, high up the Ohio, about 1,200 miles from the sea, in the year 1856-57, in its trade with Pittsburgh, still higher up, 840,000 tons were carried by water, and 40,000 by land, or about 95 per cent. by water. And this, notwithstanding that—1st. That year the river was entirely closed by frost for 1½ months, and was so low, owing to drought, for 6½ months more, that no coal could be carried, so that the river was only in good working order for 4 months.—2nd. There is frequent loss of vessels by snags.—3rd. The distance by water is much greater.—And 4th. The current is much too strong. In the lower parts of the Mississippi of course the proportion carried by water must be still greater.

And the charges are, on the Ohio and Mississippi, for long distances, $\frac{1}{14}d.$ for minerals, to $\frac{1}{6}d.$ and $\frac{1}{4}d.$ for agricultural produce for shorter distances; this is in the face of the most perfect system of railway transit. What may we expect in India, without the hindrances of frost and drought, keeping the navigation unavailable and the capital unemployed for a large portion of the year, without the risk of snags, &c., without a strong current, and, with wages at about 1-20th of what they are in America? In India the canals will be available all the year, night and day, almost absolutely without risk, with

Digitized by Google

a moderate current in the direction of the main traffic, and with perfect facilities for landing and shipping at every point of both their banks.

It is certain, from the above information, that the American States would be utterly paralysed if they were deprived of their water transit, extremely imperfect as it is; and it is equally certain that, India must continue paralysed until it has a complete system of water transit.

In the great work of Mr. Parr, Editor of the *American Railroad Journal*, giving a complete account of all the United States' Railways, in three thick volumes, he speaks of the Erie Canal (extending from the head of the Hudson Navigation, at Albany, 160 miles from New York to Buffaloe, in Lake Erie, 350 miles) thus:—"There is no "doubt that the Erie, the leading work in the system of "the New York canals, is, *by far, the most important artifi-* "*cial highway in the United States*, both in the extent of its "present commerce, and in the influence it has exerted in "advancing the population, wealth, and material interests "of the country. *Its opening in fact first gave commercial* "*value to the products of the interior.*" Such a declaration from a man so entirely connected with land carriage, and so fully acquainted with a country in which the utmost possible effect has been given to that mode of transit, is as decisive as any testimony could possibly be to the *necessity* of water carriage. The quantity of goods *arriving at tide water alone* on the Erie Canal was just below 1½ millions of tons, besides *all leaving tide water* and all the local traffic. This was in 1859, before its enlargement, which had then been in progress some years, was completed. I hear that the traffic has increased enormously since that. The *average* cost of transit, including tolls, was 3 pie (⅓rd of a penny) per

Digitized by Google

ton per mile, so that no doubt minerals were carried ata much lower rate. This canal is only 70 feet broad and 7 feet deep. The locks are in pairs, and 18 feet by 110, passing boats of 225 tons. The toll is $\frac{1}{6}$th of a penny per ton per mile, or $1\frac{1}{2}$ pie, leaving $1\frac{1}{2}$ pie for the *average* cost of carriage, including carrier's profit; this in a country where wages are 20 times those in India, affords ample room for the conclusion, that in India the cost of carriage of the lowest class of goods, on long lines of perfect water communication, will not exceed $\frac{1}{2}$ pie, or $\frac{1}{16}$th of a penny, or 3 rs. (6 shillings), exclusive of tolls, for 1,100 miles, from Roorkee to Calcutta, thus giving a "commercial value" at Calcutta to every kind of produce, and even to stone and timber from the north-west extremity of the valley of the Ganges.

The average cost of the New York canals, of which the largest is much smaller than those proposed for the valley of the Ganges, has been 12,000*l.* a mile, while the latter will not cost above 2500*l.* a mile on an average, though made of ample capacity.

I will now return to Sir Proby Cautley's "Reply."

I need not, as I before mentioned, notice all minor points *in detail.*

In answer to my objection *that there is no arrangement for disposal of the silt,* his answer is, "None further than to pass it off by the escapes and termini." But these, as in another part of his reply he himself states, do not pass it off. If a river is flowing at, suppose, 6 miles an hour, and its water is diverted into a canal where it flows at 3, a large portion of the silt held in suspension is deposited in the bed of the channel; it is not carried to the escapes or the termini, for the quantity of

Digitized by Google

silt held in suspension is in proportion to the current, and as soon as the current is diminished, a portion of the silt is deposited. Some means therefore must be adopted for the disposal of it. The want of this is one of the mistakes that I made in planning the Godavery works. The only plan I can think of for this is, to make the heads of the canals very wide, so that the silt may be chiefly deposited there, and then to keep large dredges constantly at work on that spot, because there, they would be no hindrance to the navigation.

Sir Proby Cautley proceeds to answer me about *the making of the Solani Aqueduct of the same width as the canal.*

One remark of his is, that he did not consider himself justified in attempting a rapid run of water over *this elevated embankment.* I was was not speaking of the *embankment,* but only of the *masonry aqueduct.* My objection was to the *breadth of the masonry being the same as that of the canal,* on the ground that, though it was necessary to keep the current under 3 miles an hour, in *an earthen channel,* for fear of cutting up the bed and sides, yet there was nothing to prevent a much higher velocity, *in the masonry.* In his remarks, however, I should observe, he mixes up together the two totally different points on which I had spoken. One of these was, *the breadth of the aqueduct above* for the water of the canal—the other, *the length of the work for the Solani to pass under it.* I mentioned these as *two* defects, but they have nothing to do with each other. His defence of the great *breadth* of the aqueduct for the canal water is, that he made it in two channels, so that one could be shut up if it required repair, while the other was in use. There is no doubt something in such a precaution; but I do not think it was necessary. I think the risk is so very small, with such a well-constructed work as this,

Digitized by Google

that it was not worth while to spend 75,000*l.* (I think the work cost 150,000*l.*) in doubling its width, especially as it was almost certain that, *if any accident did occur it would be such as would injure both halves.* But I would not have made it more than one-third the width, and have sent the water through it at three times the velocity given to it in the canal, and so have saved nearly two-thirds of the cost. There is no objection to this plan, and the saving is very great.

With respect to the second point, that is, *the great length of the work,* he quotes from Col. Baird Smith's remarks on the Gunnarum Aqueduct. Col. Smith mentions two accidents which happened to it. Of the first he says, "Within a few "months (or probably weeks, for I forget the precise date) "after the aqueduct *was finished,* a flood rose, as I understood, "not less than 5 or 6 feet over the level of the tops of the "parapets, thus burying the whole structure under water." About this he evidently had only some confused information. The flood occurred *while the work was under construction,* before the side walls of the aqueduct were built, and went, not *over the parapets,* but merely *over the arches;* and it was a most gratifying proof of the general soundness of the work, for I suppose no bridge in the world ever stood such a test before as entirely to disappear under water while the masonry was quite new, for the men were at work upon it when the flood came, and that was only 5 months after the aqueduct was commenced, though it has 49 arches, and is 2300 feet long. It was not the least injured. We had indeed great reason to be thankful that it escaped such a trial. The flood had come upon us when we had no reason to expect it. The other accident he mentions was a real one. It did not happen as Col. Smith's correspondent tells him; the arches were not cracked by the side walls

Digitized by Google

falling in upon them, but a much worse thing, viz., by the sinking of the foundations of one or two of the piers, owing to the water cutting through the flooring of the aqueduct, and scouring out the sand till the piers sank. This is one of the many things that have occurred in our Madras works, by which we have learnt what we did not know before, or at least had not such clear ideas of. The injury, however, was very partial, and some additional precautions were taken, which have been quite effectual. This work is a striking proof of what may be done in the way of securing a bridge against very high velocities. The water in a high fresh stands 4 or 5 feet above the *crown of the arches*, so that it flows through them at nearly three times the current of the river. The object of making it so low was to accommodate it to the level of the canal that passes over it. It has afforded us a most important lesson in canal engineering. It has now been in effective operation about 10 years. I cannot say that we have obtained all our experience without mistakes and accidents; there have been many of both; but we have found that they have helped to give us our present knowledge of hydraulic engineering in India, and a confidence which we never could have had if we had attempted nothing. By God's blessing, *all the great works there are in the main successful, and are now in profitable operation.* I say so much on this subject that, it may be understood that, I am not talking about matters that I have not fairly earned experience in.

But to return to the Solani Aqueduct. From the success of the Gunnarum Aqueduct, *which, be it understood, is built on a foundation of sand,* I am convinced that a very much less water-way might have been given to the Solani river that passes under it, and thus the length of that structure

Digitized by Google

diminished as well as the breadth, so as still further greatly to reduce the cost.

Sir Proby Cautley then says, with respect to *the canal being too narrow for the traffic at the lower end*, "With this my *irrigation* project is not concerned." But *it is not only an irrigation work.* A great expense has been incurred in locks to provide for *navigation*, and at this lower end the great expense of pairs of locks was incurred for the whole 40 feet of descent into the river evidently to provide for a very extensive traffic. What I pointed out was that the breadth of the canal was quite too small for *such* a traffic.

With respect to all these points about the navigation, what I say is, that, if the expense of locks, &c., was incurred to provide for navigation, then whatever else was necessary to make the navigation *effective* ought to have been provided. As the works are, for the want of a very moderate expenditure, the navigation is very inefficient, while *it could easily be made the most perfect communication in the world.*

Sir Proby Cautley afterwards makes some further remarks on my opinion, *that the canal head ought to have been made below the confluence of the Solani.* He thinks that I had not sufficient data for that opinion. I reply that I only wanted, one piece of information, which was, the height of the country above the river, and this by no means to any great nicety, *for it was not a question of whether the proposed new head canal must be* 10 *miles or* 50 *long.* This information I got from one of the local officers, and no doubt it was quite correct. It referred to the Futtygurh branch. As to the *practicability* of building a weir, of course I did not require any detailed information for that; I saw the Ganges in many places, and found that it was *just of the same character as our rivers*, and I know of

Digitized by Google

course *that what had been done in Madras in many places could be done there.*

Sir Proby Cautley goes on to speak of what I say in another place about a second head for the canal 200 miles lower down, and seems to confound the two together. The object of the second weir was, as I have said—1st. *To allow a portion of the water to be conveyed by the river itself to the lower level* instead of going to the expense of enlarging the canal for it all the way from Hurdwar; and 2nd. *To secure the use of the additional supply that is found in the river at the lower point.*

Sir Proby Cautley wonders at my supposing that, the cost of a weir at the confluence of the Solani would not be much greater than at Hurdwar. There is no reason why it should be much greater. The carriage of the stone for the apron, by the canal, about 20,000 tons, some 50 miles, would not be a large item. The mass of the work would probably be built of brick.

He then speaks of, mistakes in my paper as to the *precise* quantities and measurements. But I had nothing to do with *precise quantities in such a paper. None of the differences he mentions in the slightest degree affect my arguments.* He adds—"A calculation for loss by evapora-"tion on a canal 40 yards wide *of two cubic yards per hour* "is one of those extraordinarily cool dicta which defies "all inquiry." The area of a mile of canal 40 yards broad is 70,000 square yards, and as the average evaporation is about $\frac{1}{4}$ inch per day, or 1-100 inch per hour, equal to 1-3600th yard, the evaporation per mile would be *twenty cubic yards per hour.* The mistake was in writing 2 for 20 either in the calculation or the copying of my report. The correct quantity is still a matter of no importance in such a work.

Digitized by Google

I have before noticed Sir Proby Cautley's following remarks about the points at which the water should have been drawn from the Ganges. I will only add here that, he says, "experience is against them" (*i.e.*, against my views). What experience? the experience of men who have *never built or seen a large weir?* The experience of those who *have built many* is entirely for them. Which is the kind of experience to be trusted?

Sir Proby Cautley then proposes, to remedy the excessive current of the canal by cutting a *second canal* from Roorkee to the Bolundshuhur head, and dividing the water between the two; and he says, "*My belief is that the volume of "water is too great for an artificial channel carried through "a soil like that through which it passes below Roorkee.*" To this I say, my opinion on this point is, *that the volume of water is of no consequence whatever. The sole point is the current.* If that is moderate, about 1½ miles an hour, there will be no injury to either the bed or the sides of the canal, whether 1000 or a million cubic yards per hour are conveyed. We have channels conveying all quantities, from 100 cubic yards to half a million, and it never makes the slightest difference. Not a single precaution is ever taken with the largest channels that is not taken with the smallest; they are all alike, nothing in the world but simple cuttings.

And as for the discharge of such quantities over weirs, *surely when we have found out how to discharge* 200 *million cubic yards an hour over a weir* 16 *feet high in the sandy channel of a river, we need not be at a loss about the discharge of one million over a weir* 10 *feet high in a canal.*

On these accounts *I entirely disapprove of the idea of cutting another canal in addition to the enormous excavation*

Digitized by Google

already made. The channel from the top of the banks to its bed is about 24 feet deep. I would fill it to about 18 feet deep, and diminish the slope, so as to give a current under 3000 yards an hour, and it would then convey about a million cubic yards per hour at a velocity that would not touch the bed or sides. *With the enormous embankments that have been thrown up, there would surely be no risk in conveying any depth of water.*

If men argued 40 years ago that a locomotive could not draw a carriage on a railway, though it appears ludicrous now to us, yet there was really some excuse for it then; but if a man were *now* gravely to insist upon its *impracticability* it would be strange indeed. And it is exactly the same to argue now that it is "visionary" to offer to build weirs across the sandy bed of the Ganges *after exactly similar works have been in operation for nearly* 30 *years on rivers of precisely the same character.*

There is to me something very curious in hearing now, after 30 years of successful and most abundantly profitable operation of these very works, the selfsame language with which I was met when I first urged the construction of the Cauvery or Coleroon Anicut — "An anicut across the Cauvery. What a 'visionary' idea!" I thought at that time,—"if I can only get one of these anicuts built, there will be an end to all this; people will see that, what was done by the natives hundreds of years ago in the case of the 'Grand Anicut,' as it is called, on the Cauvery, with their little science and poor means, can also be done by us, and there will be an end of such exclamations." But since that, eight such works have been constructed in the very worst situations, as respects foundations, &c., without one failure (not without many accidents), and with unpre-

Digitized by Google

cedented profits, and now precisely the same cry is heard with respect to a river of $\frac{1}{8}$th the volume of water of one of those which has already been mastered, and that, not by a non-professional man, but by one of our greatest Engineers. It seems to me now that, it is as useless waiting till this sort of thing ceases, as it is to wait by the side of the Ganges at Allahabad till all the water runs off. We must be content to go on constructing these *visionary works*, which produce such *uncommonly substantial results* as we witness in Madras, and to live and die *visionaries* for our pains.

I would just recapitulate the leading points that I insist upon as, manifestly true, with reference to the project under discussion, and the plan upon which it has been executed :—

1st. It appears that, according to Sir Proby Cautley's paper, the levels admitted of water being led from the river, at the mouth of the Solani, by a channel 51 miles long, to the water-shed of the Doab at a point 94 miles below Hurdwar.

2nd. If this had been done, about 43 miles of channel would have been saved, and also *the whole* of the heavy works for crossing the great drainage from the Sub-Himalayas.

3rd. Much more than 95 per cent. of the available land of the Doab lies *below* the level of that point on the Ganges, and there was no special object in applying the water to land *above* that level rather than to those adjoining.

4th. That the weirs constructed at Madras entirely settle the question of the practicability of a weir on the Ganges at that point.

5th. That if it was a condition not to be overlooked, that water was to be drawn from Hurdwar for the irrigation of

Digitized by Google

the highest land, that did not make it necessary to bring *the whole* volume of water for the irrigation of land, some of it 300 miles distant and 600 feet below it, from that high and distant point, and across the only part of the whole tract that offers serious obstacles, the overcoming which has been a principal part of the expense incurred; but that it would have been much cheaper to lead a large portion of the water off from a lower point, making use of the channel of the river to convey it 200 or 300 miles, instead of along an excavation.

6th. That there was nothing to prevent the water being carried *partially* above the level of the surface, which would have saved three-fourths of the excavation, as well as the loss by percolation.

7th. That if these mistakes had been avoided, the works would not have cost much above one-third of what they have, and consequently have been finished in little more than one-third of the time—hence, that the works might now have been for many years in highly profitable operation.

8th. That if only on the ground that, expense has been incurred in locks, whatever further was necessary should have been done to make *the navigation effective.*

9th. That such a work can easily be made the best possible communication, carrying any quantities and numbers at a price far below any other means, and at an ample speed.

10th. That if only on the ground of the river navigation being injured by the abstraction of so much water, compensation should have been made by continuing the canal to Allahabad, as it could have been done at so small an expense.

11th. That in case of famine, the use of the canal to distribute food from the distant districts through this tract would have been at least as important as for irrigation.

Digitized by Google

I do not like to conclude this paper without once more stating what I conceive to be the sources of the mistakes that have been made up to this time in this great project. They are:—

1st. The fancy that a weir was an almost impossible work. This seems to have been the real idea that drove the Engineer up to a point 300 feet above most of the land to be watered, and 600 above the lower land that has been watered, and also where he had to cross the only difficulties that occur in the whole Doab.

2nd. The strange misapprehension respecting the immense importance of water carriage leading them to trifle with the navigation. Colonel B. Smith, even in his Famine Report, when he is insisting on the importance of communications, never once mentions the main point in the question, *the cheapness of water carriage*, but speaks everywhere as if land and water carriage were much the same things. He states in one place that the cost of carriage on a good metalled road is there 1 anna per ton per mile; and, so far as I can learn from the results of the railways, the actual cost of the great mass of traffic will not be much under that—the actual average seems to be above it; and it is certain that the profits on it are either nothing, or very little more, because the whole nominal profits are such as probably barely to cover the depreciation; and as the passenger traffic is certainly more profitable than the goods, the profit-on the latter must be extremely small indeed. Now, there is abundance of proof that goods can be carried long distances by water on an efficient canal under $\frac{1}{8}d.$ a ton, so that the saving on a million tons per annum would be above 5000*l.* a mile, while the Ganges Canal, even if its whole cost of $2\frac{1}{4}$ millions had been spent on the main lines, above 700 miles, would be only 3500*l.*

Digitized by Google

a mile; and if we deduct from that, the cost of distribution, it will reduce it to perhaps 2000*l.* a mile, even as the works have actually been constructed.

3rd. The fancy that it was necessary to convey *all* the water *below* the surface of the ground to prevent percolation, whereas the only way of preventing it was not to cut through the water-tight soil, but to carry the water partly above the surface.

I think I have given abundant reasons to satisfy any person that if—1st., the whole of the heavy works had been avoided by beginning the canal lower down; if—2nd., the excavation had been reduced by carrying the water partly above the surface; and if—3rd., part of the water had been led from the river 200 or 250 miles lower down, the works would *certainly* not have cost one-half of what they have, probably about one-third; and if—4th., the navigation had been made perfectly effective, which it could be at a small additional expense, the value of the work for navigation would be equal to that for irrigation.

Terminating thus my observations upon Sir Proby Cautley's reply, I cannot close this paper without, in the most emphatic manner, calling attention to *the imperative duty, which cannot be safely avoided, but must inevitably and should be, promptly, undertaken* by the Government, or by a private company, namely, of ascertaining and adopting, the most efficacious means for putting an end to, the positively seriously critical state of the Ganges Canal, and also for securing the construction of those works which are absolutely required to make it thoroughly effective, reliable, and successful. My views, and the works I confidently advocate, are fully described in my private Report and in this paper of observations; and I hesitate not to assert that, the practicability of those works

Digitized by Google

has been abundantly proved and placed beyond fair doubt, by actual experience, and manifested by structures of the same character, erected on a much larger scale, in more unfavourable situations, and subject to greater trials than can be found connected with the Ganges River and Canal. *Nothing short of those works will, I am convinced, be permanently useful or prudent to be undertaken;* and I earnestly entreat those, with whom the power of action rests, to allow of no delay, no excuse, but at once to enter upon *a calm, unbiassed investigation of the whole facts, the arguments which have been adduced, and the statements put forth,* and having arrived at a decision, to act with energy in order to rescue, from the apprehended total failure, a noble work of high national value, from which much has been expected and comparatively little obtained, but which, *if judiciously and properly dealt with,* may be made, humanly speaking, a certain and reliable protection against future famine, by *irrigating* and rendering cultivatable at all seasons *the whole of the Doab,* also a channel for the cheap conveyance and distribution of the increased produce, created by its own fructifying water, and likewise the means of enriching the Government, whilst securing increased wealth to the people.

To this I will only add, that one thing is certain: all the persons in any way connected with this work, both engineers and civilians, are at this moment convinced that, it is in a critical state, and must be taken up seriously, and further, that they are or were a short time ago entirely at a loss what to do.

At the risk of being accused of reiteration, I must however again protest against opinions of mine which were given *in confidence* being construed into a personal attack on any

Digitized by Google

individual, and I repeat that by my report I was not trying the *projector* but the *project*. I deem it to be the duty of every individual *possessing experience in such matters* to do all in his power to induce the utmost possible use of a national work which, through mistakes, has most certainly become a powerful instrument of obstruction and injury to the country generally, though possessing in itself vast powers of usefulness if properly treated. For my part I am free to confess a wish that I could see the Godavery and Kistnah projects taken up in the same way, their mistakes corrected, and the works completed and extended.

And this brings me to, the general question of Public Works in India; but before I make any remark upon the subject, I must desire it to be understood that I am not finding fault with any person, but merely bringing to notice a most unquestionable and most serious fact, when I observe that there has been *an entire failure to carry out the execution of those important hydraulic works efficiently hitherto.*

1st. The Ganges works have been I do not know how many years under consideration, but it is 21 *years* even since ground was actually broken for them, and they are not now finished.

Col. Baird Smith says, in par. 27 of his Report of May 25, 1861, speaking of the Doab—"The most characteristic feature of this section in reference to irrigation is, "however, the large canals by which it is traversed; these "have not reached a tithe of the development that waits "them as the various channels under construction are "brought to completion," &c. This was nearly 20 years after they were begun; and afterwards referring to the year of famine, he adds—"And observe what the losses were in "that one year. If the aggregate of these losses (of pro-

Digitized by Google

" duce) throughout the famine tract be taken at *three* " *millions sterling,* it will, I believe, be *under the truth.*" And again—" The whole *remissions of the Government revenue* " in aid of landed proprietors who have borne the loss just " indicated, will amount altogether to *about* 400,000*l.*" And further on he says—" The expenditure incurred (by " Government) in various forms, including among them " the remissions of Government revenue which have been or " will be granted, falls *not much short of three-quarters of a* " *million sterling.*"

2nd. The Godavery works were recommended to Government 18 *years ago,* and only a little more than half the land is yet watered.

3rd. The Kistna works have been in hand about 12 *years,* and not a quarter of the land is yet watered.

4th. The Pallaur works have been in hand about that time, and not half the use has yet been made of them that they were intended for.

5th. The East Coast Canal was ordered by Lord Dalhousie about 15 *years ago,* and it is still in fragments for want of the connecting links.

6th. The Upper Godavery navigation was urged upon Government about 12 *years ago,* and actually commenced 7 *or* 8 *years ago,* and only some 100,000*l.* or 150,000*l.* has yet been spent on it, while the whole of *Nagpoor* and much surrounding country—the tract where the finest cotton is produced—is entirely shut out from all effectual improvement till that communication is open.

In the Godavery and Kistnah all the heavy work is done and yet further porgress is almost stopped, while the additional outlay required would return more than 100 per cent. I believe the remaining 400,000 acres in the Godavery Delta

Digitized by Google

would require about 100,000*l.* for the distribution works, and they would pay to Government alone in water-rate about 150,000*l.* a year. The same with the Kistnah works. And now, under the new financial arrangements, instead of those vital works being pushed on faster, the works are almost entirely stopped, a mere trifle having been allowed for all the new works in Madras this year, and there is no symptom of this contemptible system of false economy being abolished. We have a further specific and most notable instance of the utter failure of the Government management of irrigation works in the proceedings respecting the late famine in the North West. In this case there were several months of warning, and consequently ample time both to consider and provide for the time when the actual pressure of starvation came. As matters were managed, 140,000 people, already starving, were employed on public works, when they were so reduced that many died daily, and of course numbers were quite unfit for work. Now, had there but been arrangements made beforehand, a large staff of superintendents might have been ready with extensive works marked out, and large stores of food and tools, and probably several hundred thousand of labourers might have been easily secured, and in one year a progress made in the works which otherwise would not have been made in less than five or ten years. Thus this terrible calamity might have been turned into a blessing. Exactly the same took place in Madras in the famine that occurred in Bellary. The Government were warned of the certain approach of the famine, months before it was seriously felt, and were entreated to provide for it by having all in readiness to commence some important work. But this was refused, and not a finger was moved till the terrible calamity

Digitized by Google

actually came, and then the Government found themselves with 100,000 starving people on their hands, most of them too weak to work, without a staff of officers, without works marked out, without stores of food or tools. In this utter confusion 120,000*l.* were spent, and the collector reported that the work done was certainly not worth more than 30,000*l.* Such an opportunity, if taken advantage of with ordinary prudence and forethought, placing at the disposal of the Government a large proportion of the working population of a district, would actually be, perhaps, *upon the whole*, rather a blessing than a calamity. A noble and extensive work might be carried out in a single year that would give the district lasting prosperity far beyond what it had before. Nothing therefore can be more certain than the fact that, there has been the most lamentable failure in the management of these matters under the Government arrangements.

But further, all that has been done has been mere patch-work—a piece here and another there only as they were pressed upon the Government by subordinate officers. No statesmanlike, comprehensive view has ever been taken of the question of the Irrigation and Navigation of India, as a whole. Were all the works now under execution completed, there is no plan under consideration for connecting them. And even when a step is taken by the Government in the right direction, by offering to a private company projects, as in the case of Oudh and Behar, conditions of a nature too stringent to be accepted with a chance of raising capital, or if accepted, too unjust to be enforced, are introduced into the contract *by a subordinate;* and when these conditions are objected to upon reasons stated, the papers have been kept in a pigeon-hole for more than a year without anything

Digitized by Google

being done about them: they have not, I believe, even *to this day* been brought before the Council of India.

Surely it is time this subject were taken into full consideration. *The Government have certainly failed to carry out these essential works effectively.* Why should not *a fair trial* be given to an English association of gentlemen acquainted with India and its wants, who are willing to undertake such works, and who may thus be made the means of bringing, to the advancement of Indian agriculture and prosperity, the almost boundless wealth which England can well bestow, and will willingly invest, if once her capitalists are satisfied that, money can be so employed profitably and safely? Another and incalculably good effect, which will flow from the establishment of such an agency, will be, the introduction of an additional, large and carefully-selected, body of educated, scientific engineers and many valuable Western improvements, whilst the Government being thus released from all anxiety and from all *financial risk*, in connection with such works, will then be enabled to confine its own direct operations and energies to matters purely of a governmental character alone, and those, its proper actions, will be less impeded than they have been heretofore, its duty as connected with the works undertaken being solely one of watchfulness for the prevention of public injuries and wrongs.

To adopt this course will not be introducing a *new principle*, but only carrying out one that has been explicitly and repeatedly acknowledged by the authorities, both in India and in England—viz., that the Government should only carry on material improvements directly, till other effective agencies are raised up, and no longer; and that this is true political economy needs no argument. Look only at the

Digitized by Google

wonderful effects realized wherever the use of British capital and enterprise has been *freely permitted*, and you may receive some idea of, the enormous benefits which will accrue to India under a generous and wise encouragement of those who present themselves as pioneers to, clear the way for the general flow of funds for like purposes to that country. *Can there be a more legitimate opportunity for a real commencement and establishment of such a policy than the Ganges Canal presents?* At this moment that work is a source of alarm, annoyance and trouble, to the Government, whilst *a large expenditure cannot be avoided by them* if they retain it in their own hands; and I will add that, if the correct steps are not taken, that expenditure will produce further loss, further annoyance, and further disappointment only. From all these inconveniences and troubles, from all this expense, and from all future liability and risk, they may at once relieve themselves, and at the same time raise a foundation of confidence upon which the people of England will act with alacrity and effect, for the permanent benefit of India. Let *all in power unite in giving to the experiment a hearty support*, so that success may be secured as surely as possible, and so that, if failure should unfortunately happen, it may not be attributable to want of co-operation on their part. With all united in one desire we have surely fair data for concluding that the result cannot, however, be at all problematical.

The advantages to be thus gained are so large, nationally speaking, that even *great pecuniary sacrifices* would be justifiable if necessary to secure them, but these are not required; on the contrary, the Government may participate in the profits realized.

Could there, I will again ask, be selected, a more legiti-

Digitized by Google

mate subject for the consideration of Government during this time of rest?

For the *extension* of works of irrigation in the Doab in connection with the Ganges Canal, the Government have already expressed their anxiety, as will be seen in the following extract from their instructions to Colonel Baird Smith:—

"A further, and a very important, point to which Govern-
"ment would wish your enquiries to be directed is the
"*extent* to which it may be practicable and wise to push
"forward means of irrigation in the upper provinces, with
"the view of giving the means of fertilizing a larger area,
"and thus making more effectual provision against the
"recurrence of future seasons of drought."

Such being the case, will it not be plainly short-sighted policy, and specially unjust towards the inhabitants of the Doab, to discourage, or illiberally treat, those who are prepared to execute, with private capital and at once, the works thus pointed out as beneficial and necessary? for, whatever may the result to them, the mere introduction and expenditure of a large amount of English money, apart from the effect of the works, cannot be otherwise than productive of great local good.

It is most certain than, an extensive system of irrigation and navigation, by whomsoever executed, would extinguish the most oppressive and ruinous of the taxes, and nothing could be compared to them for giving intelligible proofs to the people of the benefits of a Christian Government. However difficult it has been found to teach *English statesmen* the value of water, every native ryot can understand it perfectly, and wherever water has been given them they thoroughly appreciate the action of our Government and the benefits thus bestowed; and, as illustrative of this, I

Digitized by Google

will conclude by quoting from Sir Emerson Tennant's work on Ceylon, a sentence, which all who know India will admit might have been written of that country as aptly as of Ceylon:—

"It is no matter of surprise that the kings who devoted "their treasures and their personal energies to the forma- "tion of tanks and canals have entitled their memory to "traditional veneration as benefactors of their race and "country. In striking contrast is the pithy remark of the "author of the *Rajavali*, mourning over the extinction of "the 'Great Dynasty' and the decline of the country, "that, '*because the fertility of the land was decreased*, the "'kings who followed were no longer of such consequence "'as those who went before.'"

May the memory of the present rulers of India, like that of the "Great Dynasty" of Ceylon, be entitled to traditional veneration, and may those rulers, by taking advantage of the opportunity now presented, justly earn the title of benefactors of the land, and of its myriads of inhabitants placed under their guidance and protection, and show them that, enlightened and invigorated by God's own Word, we are at least equal to heathen rulers.

NOTIFICATION.

HAVING received the following letter from Mr. Westwood, the Secretary to the East India Irrigation and Canal Company, I feel that I cannot better effect the object there desired than by printing such letter entire with this Pamphlet.

The circumstances referred to by Mr. Westwood will be

Digitized by Google

found described in the Memorandum No. 3, inserted at page 41.

It is certain that, the idea that, I should examine the Valley of the Ganges was entirely the Company's own, and they have incurred a large expense in sending me out for that purpose, and in the salaries of the officers employed with me, so that their sole right to these professional opinions cannot be questioned.

A. COTTON.

Tunbridge Wells, 22nd Jan., 1864.

"The East India Irrigation and Canal Company,
"27, Cannon Street, E.C.,
"London, 20th Jan., 1864.

"MY DEAR SIR ARTHUR,—Looking to the circumstances "under which your private Memorandum or Report upon "the Ganges Canal was written, I am sure you will agree "with me when I say its contents, with the whole of the "plans, professional opinions and suggestions you have there "put forth, belong absolutely to the East India Irrigation "and Canal Company, and can be fairly and properly acted "upon, or put in force, by them alone, or by others, with "their assent first obtained.

"As this Report has been already printed for *private* "*circulation*, and as you are about to reissue it in a like "manner accompanied by some further observations of "yours in explanation of its statements, I cannot help "asking you, as a measure of protection, to add a notifica- "tion to the above effect, and so that, all who read the "Report and observations may at the same time be made "aware of the proprietory right of the Company thereto.

"Yours sincerely,
"J. WESTWOOD.

"Major-General Sir A. Cotton, R.E."

Digitized by Google

Digitized by Google

The East India Irrigation and Canal Company.

27, Cannon Street, E.C.

London 26th January 1863

My dear Sir Proby Cautley

I have only this moment received the first supply of the Pamphlet consisting of a few copies and I only send you one that you may see its contents before you leave Town — If you will kindly let me know the place where you would wish the further copies you are to have sent I will forward them with pleasure

Yours very truly

Westwood

Colonel Sir P. T. Cautley K.C.B.

Digitized by Google