

REPORT



GANGES CANAL COMMITTEE,

CONVENED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA IN COUNCIL
(No. 20,410c. OF GOVERNMENT OF INDIA, PUBLIC WORKS DEPARTMENT, DATED
24TH FEBRUARY, 1866), TO DECIDE UPON THE PROPRIETY OF
PROCEEDING, AS PREVIOUSLY DETERMINED WITH

MAJOR CROFTON'S PROJECT FOR REMODELLING THE
GANGES CANAL,

OR

OF STOPPING ITS PROGRESS, PENDING THE PREPARATION OF A DETAILED PROJECT

ACCORDING TO THE VIEWS OF MAJOR-GENL. SIR ARTHUR
COTTON, R.E., K.S.I.

WITH A COMPARISON OF THE COST AND ADVANTAGES OF THE TWO PLANS.

ROORKEE:

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JAMES JOHNSTON, SUPERINTENDENT.

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Report of a Committee convened by Order of His Excellency the Governor General of India in Council (No. 20,410c., of Government of India, Public Works Department, dated 24th February, 1866), to decide upon the propriety of proceeding, as previously determined, with Major Crofton's project for remodelling the Ganges Canal, or of stopping its progress, pending the preparation of a detailed project according to the views of Major-General Sir Arthur Cotton, R.E., with a comparison of the cost and advantages of the two plans.

President.

COLONEL COMMANDANT EDWARD LAWFORD, R.E.

Members.

LT.-COL. J. C. ANDERSON, R.E.

GEORGE SIBLEY, C.E.

LT.-COL. J. G. FIFE, R.E.

HUGH LEONARD, M.I.C.E., F.G.S.

The Committee having met at Cawnpore on the 31st March, proceeded, accompanied by Major J. Crofton, R.E., to examine the Canal Works from the river Ganges up to near the Dubowli Falls, and also the river itself in the vicinity of the town. They then went to Agra and examined the river Jumna at that place, and for a few miles lower down. Proceedings of the Committee.

The Ganges was examined near Rajghat, opposite Allygurh, and the Committee proceeded for about eight miles along the canal above Nanon, after inspecting the Regulating Works at that place. The river Jumna was examined at the confluence of the Hindun, and afterwards at Alee, a small village near the ruins of Toghluabad, about ten miles below Delhi.

The Committee then returned to the Ganges at Gurmuktesur, and from thence marched along the edge of the high land, to the confluence of the Solani torrent with the Ganges, examining its junction with the strip of low ground along the margin of the river nearly the whole way, and more carefully in the vicinity of the Solani. Crossing the high land to the canal, the Committee then proceeded along its banks from the Jaoli Falls to the head at Hurdwar, examining each important work as closely as circumstances permitted, and termina-

ting their inspections with the temporary bunds in the river and the head works of the canal.

The Committee also saw some of the places near Hurdwar from whence stone has been obtained for the canal works.

Conclusions arrived at.

After much discussion and careful consideration of every point bearing on the subject, the Committee have arrived at the following conclusions, on grounds explained in the subsequent detailed reports.

Weir across the Ganges near the Solani.

£1,128,681.

I. That the construction of a weir across the Ganges below the confluence of the Solani with other necessary works for supplying water to the canal, at an estimated cost of Rs. 1,12,86,314 cannot be recommended.

Weir and canal at Rajghat.

£1,130,417.

II. That the project for opening an additional canal head, including the construction of a weir on the Ganges at Rajghat, or other point in that part of the river, at a cost of Rs. 1,13,04,170, for bringing under irrigation lands not now watered by the canal is feasible, but should be held in abeyance until the probable returns appear more proportionate to the outlay than at present.

Weir across the Jumna, and canal for irrigation.

£354,570.

III. That the construction of a weir across the Jumna at Togh-lukabad with a canal for the irrigation of that part of the Doab below Allyghur, not under the influence of the Ganges canal, at a probable cost of Rs 35,45,701, inclusive of branch channels, is practicable, and that the project should be further investigated; but they are of opinion that it cannot be substituted for any portion of Major Crofton's project.

Major Crofton's project.

IV. That Major Crofton's project for remodelling the Ganges canal should be proceeded with, subject to the modifications suggested in this Report.

Weir at Hurdwar.

V. That the construction of a permanent weir across the Ganges at Hurdwar, though not indispensable while the present reduced quantity of water is passed down the canal, will become a matter of absolute necessity in order to maintain without risk of interruption the full supply of 7,000 cubic feet per second.

PROPOSED HEADS FOR THE GANGES CANAL.

PRELIMINARY OBSERVATIONS.

1. As the Committee think that the peculiarities of the Ganges are somewhat remarkable, and that a comprehension of them is indispensable before an opinion of any value can be formed as to the relative advantages of different sites for the opening out of new canals, they will endeavour to describe them.

Peculiarities of Ganges somewhat remarkable.

2. The Plains in the N. W. Provinces, unlike the Deltas on the East Coast, are far above the limit of the inundation of the rivers. In the course of ages the Ganges and the Jumna have scooped out their beds to a far lower level than they must have had at some former period, and this operation has completely changed the relation of the land with the rivers. The N. W. Provinces for a distance of several hundred miles from the base of the hills are thus formed of a vast plateau, which rises many feet above the highest flood level of the Ganges and Jumna. This elevated tract is termed the Bangur, in contradistinction to the Khadir, or the strip of low land in the actual valleys of the rivers, and which is more or less inundated by them during high floods. The fall of the Bangur is not exactly the same as that of the rivers; or, in other words, the plane of the surface is not parallel to the surface of the rivers. That of the Ganges is more elevated near the hills than it is at any point lower down. For instance at Sookertal, at the distance of 34 miles from the hills, it is 80 feet above the flood level of the Ganges opposite; and at Cawnpore, 350 miles below Hurdwar, the elevation is only 38 feet. But the difference is in a nearly regular gradation, so that knowing the height of the Bangur above the river at any two points, say 40 miles apart, it may be assumed with confidence that the height at the point midway between them would be almost exactly the mean of the other two.

Character of the Plains in the N. W. Provinces, in relation to the rivers flowing through them.

3. A range of low hills called the Sewaliks runs in a nearly straight line across the head of the Bangur land from the Ganges to the Jumna. From their base to the junction of the two rivers at Allahabad, the great plain is unbroken by a single elevation larger than a sand hillock.

Unbroken plain from Sewalik hills to Allahabad.

4. The drainage water from the southern slopes of the Sewalik

Drainage from the Sewaliks.

range has to find its way into the Ganges and Jumna. The portion due to the latter, that is the Western section, runs for the most part through the Bangur, and united with the minor drainages form the river Hindun which joins the Jumna below Delhi. But the drainage courses on the eastern section of the Sewaliks turn off abruptly towards the Ganges, constituting a series of torrents which have completely altered the character of the portion of the Bangur traversed by them, that is along a distance of about 20 miles, extending between the well known towns of Hurdwar and Roorkee. Hurdwar is on the east flank of the Sewaliks and close to the Ganges; Roorkee is on the Bangur land beyond the influence of the hill drainage.

The country slopes along the drainage courses towards the Ganges between Hurdwar and Roorkee: great expense of carrying canal across the drainage.

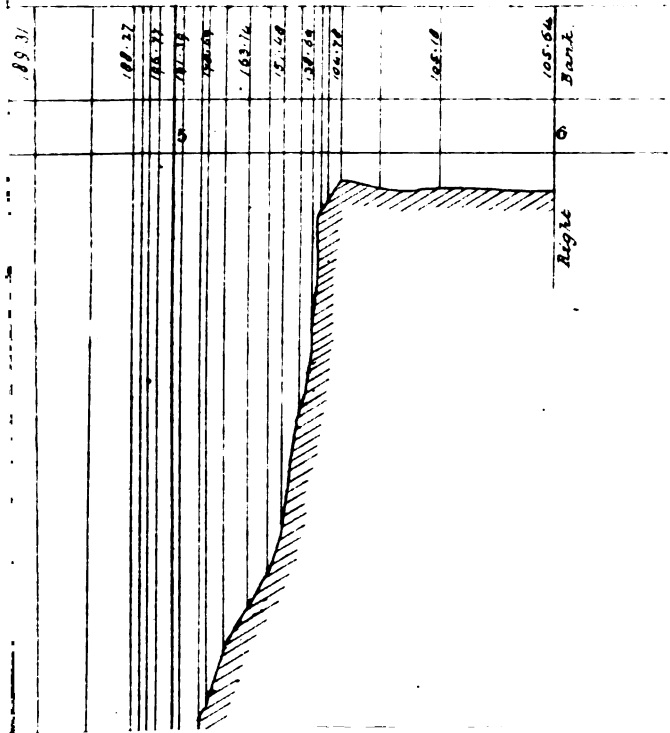
5. Thus the original formation of the Bangur from Hurdwar to Roorkee is broken. It has in fact been washed down by the torrents, which have thus formed a plane sloping towards the Ganges. But this plane also has a slope parallel to or along the Ganges, so that when selecting the line for a Canal to open from the Ganges at Hurdwar, the Engineer could obtain the required fall (indeed there was more than sufficient), and could at the same time work up the course of the drainages, so as after crossing the last of them, to be able to enter the Bangur land, in a moderate cutting. Thus the point selected for crossing the Solani, the last of the hill torrents, is 80 feet below the head of the canal at Hurdwar, but it is 70 feet above the level of the Ganges immediately opposite. The aqueduct across the Solani raises the sole of the canal 20 feet, and the level of the Bangur at Roorkee being 45 to 50 feet below the head of the canal; it can be entered in a cutting 10 to 15 feet in depth. Besides the advantages thus gained by opening the canal at Hurdwar the two other important objects have been attained. I. The water from the river enters the canal charged with much less silt than would have been the case had the head been lower down. II. The channel being of a comparatively permanent nature, the sluice and regulating works are secure against the action of the stream, which can be more easily controlled, and by temporary arrangements more easily diverted towards the mouth of the canal, than at any point below. On the other hand, the Hurdwar head involved an enormous expense in masonry works for the Solani and other hill torrents which the canal had to cross, and for overcoming this excessive slope of country.

Sir A. Cotton in favor of a head near Sookertal.

6. Sir A. Cotton maintains that it would have been far better to have opened the canal head in the first instance near Sookertal, below the confluence of the Solani with the Ganges; and that even now, instead of spending a large sum to improve the existing line, it would be preferable to open a new head about Sookertal.

Width of Ganges at Sookertal.

7. The Committee refer to this point, and find that the valley of the Ganges is four miles wide. The river is only about half a mile in width during the dry season, but in high floods the whole of the valley is submerged.



is submerged.

8. The Khadir, or low land forming the valley, is formed of a crust of alluvial soil, which may vary from the thickness of a few inches to a yard or more, overlying pure and exceedingly fine micaceous sand, which extends to an unknown depth. The Khadir everywhere possesses the same character, but is wider at one point than another; and while in some places the dry weather channel runs nearly through the centre of it, in others it may run on one flank or under the foot of the Bangur, as for instance at Rajghat, Futtehghur, and Cawnpore.

Nature of Khadir or valley of the Ganges.

9. The Khadir is intersected by deserted arms of the river, some of which have become choked by deposits, till there is only a depression to mark their course. The Khadir cannot properly be termed the channel of the river though mostly inundated in high floods; and it is liable to be, and frequently is, encroached upon by the action of the stream, so that at no single point can it be said to be safe from its influence. The experience of some of the Members of the Committee on the Ganges in Bengal, the Punjab rivers, and the Indus in Scinde, could furnish proofs of the extraordinarily rapid and extensive action of the Himalayan rivers in eroding their banks and altering their courses. Instances could be adduced of villages and trees being carried away bodily, even in ordinary floods, not by direct action of the stream during inundation, but by its undermining action before it rose to the level of the bank. The sand is sucked away by the current when the river is rising or falling, and the crust of stiff alluvial soil falls in masses by its own weight. There is thus no stability in the Khadir. If embanked, the action of the river being on the sand at a low level, the embankment would have no strength to resist the stream, and no material is procurable on the spot for protecting the foot of the slope.

Khadir frequently encroached upon by the river.

10. It would be irrelevant to seek for examples of the destructive and changeable character of the Himalayan rivers at points at a distance from those which do not more or less nearly concern the Ganges canal, but below Sookertal, the very point which Sir A. Cotton has selected as the most suitable head for the canal, the river instead of flowing close to the foot of the Bangur land, as it is shown in the Trigonometrical Survey sheets, has now a course more than one and a half miles to the eastward, while the confluence of the Hindun with the Jumna, about 20 miles below Delhi, which Major Crofton has similarly pointed out as a likely place for a head to the canal, is now four miles lower than it was, when the Trigonometrical Survey was made.

Changes at Sookertal on the Ganges, and at the confluence of Hindun with the Jumna.

11. The banks of the Godavery and Kistna are formed of alluvial soil containing a large proportion of clay down to and below the summer level of the water: here and there strata of sand are to be seen, but as a rule the banks are firm.

Banks of Godavery and Kistna more permanent.

12. On the Ganges it is different. Sir A. Cotton seems for-

Sir A. Cotton and

Major Haig, on the Godavery.

Professional Papers, Madras Engineers, Vol. III., p. 190.

Parliamentary Blue Book on the Upper Godavery, 1862, p. 75.

Works for control of Ganges require to be on a more extensive scale than those on the Godavery.

merly to have thought so also, as will be seen from the following extract from one of his Reports on the Godavery.

“It must be observed that these changes, from the action of the river on its banks are much slower on the Godavery than in the Coleroon and Cauvery, and as it seems also on the Indus and Ganges ; so that there is plenty of time to take the necessary precautions ; and the stone we have here at hand is a material for barriers far beyond the power of the stream to remove, even though in pieces of the size of the fist.” “In comparing the present state of the river with the map constructed 30 years ago, it will be seen how very slowly the encroachments of this river proceed.” Major Haig bears testimony to the same effect. The following is an extract from his Report, dated 3rd February, 1862. “In the first place the Godavery differs from the Ganges in two very important particulars. Its banks are but little liable to erosion and subject to little change. The changes which take place on the Ganges in the course of a few weeks or months would be on this river the work of a century, or rather, it would be more correct to say that the country along its banks presents incontestible proofs that no material alteration has taken place in the position of the channel for ages. In the second place, the material of which the bed is composed is a large coarse grained sand, totally unlike the fine powdery sand of the Ganges, and therefore requiring a very much more powerful current to displace it.”

13. The obvious conclusion to be drawn from the above facts is that, although the Ganges for a considerable distance from the Himalayas discharges during floods, a very much smaller body of water than the Godavery, yet owing to the weakness of its banks and the long continuance of its floods, it is so much more destructive than the latter, that works on a more extensive scale in proportion to its discharge would be required to control it.

HEAD WORKS NEAR SOOKERTAL.

FLOOD DISCHARGE AND LENGTH OF WEIR REQUIRED.

Flood discharge of Ganges at Sookertal.

Ganges Canal Report, Vol. II., p. 465.

14. The Committee have no means of ascertaining with any high degree of accuracy the flood discharge of the Ganges. Mr. Login estimated it at between 180,000 and 190,000 cubic feet per second at Hurdwar; not however including the quantity discharged by the Myapoor Dam and the canal, which would probably amount to 20,000 cubic feet per second more. Sir Proby Cautley again estimates the flood discharge of the Solani at 84,000 cubic feet per second, and the discharge of the other large drainages between the Solani and Hurdwar, must amount to at least as much more. A considerable body of water must also enter at the opposite bank of

the river. Hence it may be concluded that the flood discharge of the Ganges below the confluence of the Solani would be much greater than at Hurdwar. From the cross section which has been taken at Sookertal below the Solani, combined with the surface fall, it is found that a rise of $13\frac{1}{2}$ feet above the ordinary low level, would give a discharge of 516,000 cubic feet per second; but this is probably an extraordinarily high flood which might not be experienced under an interval of 20 years. According to the Registers, which were kept at Cawnpore and Futtehghur from 1843 to 1853, the highest flood at the former was 13 feet 8 inches, and at the latter 10 feet 8 inches, above low level. The highest rise at Cawnpore is probably attributable to the influx of the Ram Gunga, and 10 feet 8 inches, or say 11 feet, is more likely to represent the rise between Futtehghur and Hurdwar. Applying this to the section at Sookertal, the Committee find the discharge would be 279,000 cubic feet per second. Taking Sir A. Cotton's estimate of the flood discharge of the Godavery, at 1,500,000 cubic feet per second, and that of the Ganges at 280,000 cubic feet; it might be assumed that if the rise of the flood were the same in both cases and the circumstances in other respects similar, a weir of less than one-fifth the length of the Godavery anicut would suffice for the Ganges at Sookertal. As the length of the former is about 12,000 feet; the length of one for the Ganges would thus be about 2,200 feet.

15. But the circumstances of the two rivers differ to a notable extent. The Ganges discharges a considerable body of water in the dry season, with a depth in mid channel of between 9 and 10 feet, and the floods rise from 10 to 14 feet above the level. The Godavery carries a comparatively small body of water in the summer. The surface is only 3 or 4 feet above the bed, while the flood rise to the height of 30 feet. The crest of the Godavery anicut is 14 feet above the bed. The passage of the flood water is therefore 16 feet deep. The length of the work being 12,000 feet; the mean velocity will be $\frac{1,500,000}{16 \times 12,000} = 8$ feet per second nearly.

16. Sir A. Cotton, in one of his pamphlets, suggests a solid weir for the Ganges, 7 feet high above summer or low level. If the length of the weir were to have the same proportion to the discharge as the Godavery; and if, as Sir A. Cotton intended, there should be no perceptible afflux or heaping up of the water above the work, it would, as above-mentioned, be 2,200 feet long, so that as the rise in flood is 11 feet, the velocity would be $\frac{280,000}{2,200 \times 4} = 32$ feet a second nearly, or four times as much as that of the Godavery. If the length of the weir were to be increased to 4,000, the velocity would then be $17\frac{1}{2}$ feet per second, or still very much greater than that of the Godavery; but if the height of the weir be cut down from 7 feet above low water to 5 feet, there would then be a velocity of $\frac{280,000}{4,000 \times 6} = 11\frac{2}{3}$ feet per second,

Low water compared with flood level of Ganges and Godavery.

Length and height of weir suitable to Ganges.

or nearly 8 miles per hour. The afflux of the water above the natural level at that height of flood would be less than $1\frac{1}{2}$ foot; there would therefore be no cause for apprehending injurious flooding of the Khadir. The above velocity corresponds very closely with that of the Kistna anicut, with a depth on the crest of 17 feet. Owing to the curve formed by the water in falling over the dam during moderate floods, the depth of water on a portion of it is less than at the crest, and the velocity is then considerably higher. There would be this same thing with the overfall on a weir on the Ganges. Were the discharge during an exceptionally high flood to amount to 500,000 cubic feet per second, which would be the case if the river rose to $13\frac{1}{2}$ feet above summer level, the velocity would then be $\frac{500,000}{4,000 \times 8.5} = 14$ feet 7 inches per second, or 10 miles per hour.

Length of weir proposed at 4,000 feet: height above low water 5 feet.

17. The length of the Kistna anicut at Bezwada is 3,600 feet, and its height above the bed of the river is 20 feet. What is considered suitable for the Ganges is a weir 4,000 feet long, and a height of 5 feet added to the ordinary depth of the river during the dry season, or in all 15 feet above the deep bed.

Additional height of 2 or 3 feet to be gained by moveable planks.

18. For the supply of a canal the surface might be raised in the dry season as suggested by Sir Arthur Cotton, by means of iron posts and moveable planks, to a height of 3 feet at the utmost above the crest of the weir, or 8 feet above low water level; but the Committee consider that 2 feet for the planking is as much as could be calculated on in practice, and that the weir would either have to be raised or the channel deepened one foot additional.

Discharge of Ganges at Sookertal during the dry season.

19. The discharge of the river near Sookertal was measured in April of this year, and found to be 5,300 cubic feet per second, while a supply of upwards of 5,000 cubic feet per second was entering the canal at Hurdwar, a portion of the latter having been returned to the river by the mill escapes. The river was then slightly higher than it had been during the winter, and allowing that the present supply of the canal is maintained, 5,000 cubic feet would be the most that could be counted on as available at Sookertal.

Capacity and fall of channel to carry 5,000 cubic feet per second.

20. A channel 180 feet bottom width, side slopes 2 horizontal to 1 vertical, and with a fall of $5\frac{1}{2}$ inches per mile, would discharge that quantity with a depth of 10 feet, and velocity of $2\frac{1}{2}$ feet per second. The latter is the highest the lighter kinds of soil could stand, while any reduction would render necessary an additional width of channel and an additional expense, besides causing an increased deposit of silt. The bed of the channel would thus be 2 feet below low water level of the river.

Most suitable site for a weir at Raolee Ghât, $4\frac{1}{2}$ miles below Sookertal.

21. The most suitable spot for the head to the canal in the neighbourhood of Sookertal is at the bridge of boats, $4\frac{1}{2}$ miles below that village, known as the Raolee Ghât. The level of the surface of the river in April was 206 below the head of the Ganges canal, and

the head of the proposed new channel would therefore be 208 feet below the same datum.

22. The bed of the Ganges canal at the $116\frac{2}{3}$ mile from Hurdwar is 242 below the head of the canal, the distance of the site of the proposed weir to this point, measured along the line which is considered best calculated to meet Sir A. Cotton's views, is 70 miles, and the fall required to carry a supply of 5,000 cubic feet a second with a velocity of $2\frac{1}{2}$ feet per second, and depth of 10 feet, being $5\frac{1}{2}$ inches per mile, there will be $\frac{70 \times 5\frac{1}{2}}{12} = 32$ feet 1 inch, as the total fall from the head. Adding this to the relative level above-mentioned 208 feet, gives 240 feet 1 inch, which corresponds closely enough with the level of the present canal bed at $116\frac{2}{3}$ mile.

A channel from the weir to the main canal would be 70 miles long.

23. Before entering upon an estimate of the cost of constructing a weir across the Ganges, the Committee propose to specify the approximate cost of the channel. It would be carried along the Khadir or low land for a distance in all of 29 miles. The surface of the Khadir falls much more rapidly than the proposed bed of the canal, and as the total height of the Bangur land above the Khadir is between 50 and 60 feet, it is desirable, in order to avoid a cutting of that depth, to carry the bed of the canal for some distance above the level of the Khadir, or in other words within embankments. For the last 13 miles of this section of the canal it is proposed to follow the base of the Bangur land, as the ground is considerably higher there than the general level of the Khadir. It however presents great irregularities. The edge of the Bangur is cut up by ravines, some of which extend back to the distance of about half a mile, and their beds are only slightly above the Khadir level. The section therefore presents a series of sharp undulations, which will necessitate a cutting in one place, and a heavy embankment in another. According to the arrangements proposed, the maximum height of the water level will be 24 feet above the ground, and as the soil is generally very sandy, this is considered as much as could be allowed with any degree of safety. A simple earthen embankment would not be sufficient along a portion of the channel under consideration. Puddling would be the most effectual mode of preventing leakage, but as suitable earth would have to be brought from a distance, the Committee recommend, as an addition to the ordinary soil obtainable on the spot, a rough concrete wall in the centre of the bank for ten miles out of the whole distance of thirteen miles. This would also have the effect of protecting the bank against vermin, a precaution which the Committee consider to be very necessary. Only one embankment where the channel runs close to the Bangur is allowed. The water is supposed to stand back in the ravines, which would thus form silt traps, but the raising of the bed would only be a question of time, and sooner or later the drainage water would have to be carried under the channel, or a large body of silt would be brought into it; for the drainage courses, though

Line of channel through Khadir described.

embracing an insignificant area, drop from the Bangur 50 feet above the level of the channel, and the erosion must evidently be considerable.

Drainage works ultimately necessary.

24. A catch-water drain carried along the Bangur behind the head of the ravines, would cut off part of the drainage water, but still it is considered that the portion of the channel affected by it would always be liable to damage, and that the ultimate cost of the work is likely to be much greater than an approximate estimate based on a simple section of the ground would show. In taking the cost of this part of the channel into consideration the additional expense of constructing under-tunnels and catch-water drains should not be lost sight of.

Objection to high embankments.

25. Some of the Committee consider that it would be objectionable to carry an embanked channel through the Khadir, with the surface water more than 4 or 5 feet above the level of the ground: that in consequence of the sandy character of the soil, embankments could not be guarded effectually against excessive percolation or breaches, excepting at a much heavier outlay than the present estimate provides for. They would further remark that the large body of drainage water that will be admitted into the channel, will increase the danger of breaches, and that in the event of the bank giving way in the rains, it could not in all probability be repaired till the next dry weather.

Deep cutting through Bangur land, and masonry works.

26. At the end of the 29th mile the channel would enter the Bangur in a cutting of about 35 feet, which would work out to 15 feet at the 52nd mile. From thence to the junction with the present line of canal the cutting would be moderate. Masonry works are allowed for on the scale of Major Crofton's estimate for the 1st section of the "alternative line," proposed by Sir P. Cautley (after deducting the cost of the falls and regulator at head), which was to have the same capacity as the channel now under consideration. The rate allowed for contingences and establishment, is also the same as in Major Crofton's estimate. The masonry works would be very heavy as the channel from beginning to end is carried across the drainage of the country. No separate allowance is made for catch-water drains or for the masonry works which will eventually be required to dispose of the drainage of the Bangur where the line of channel runs at its foot.

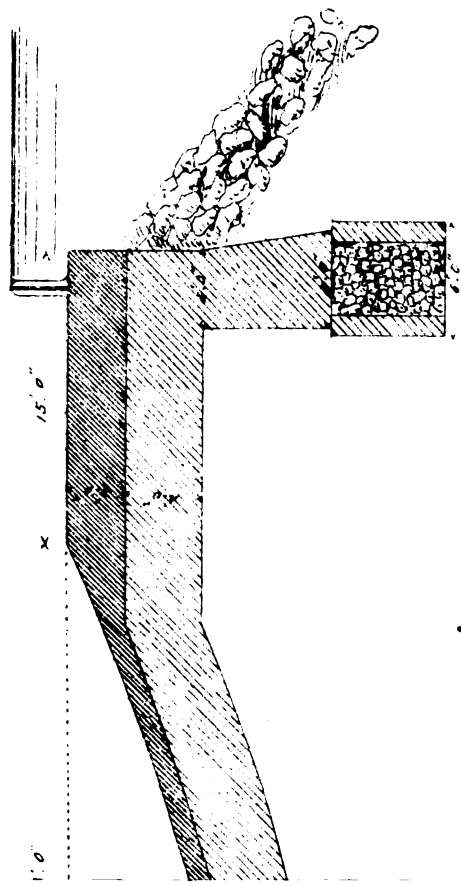
Estimate of cost of channel.

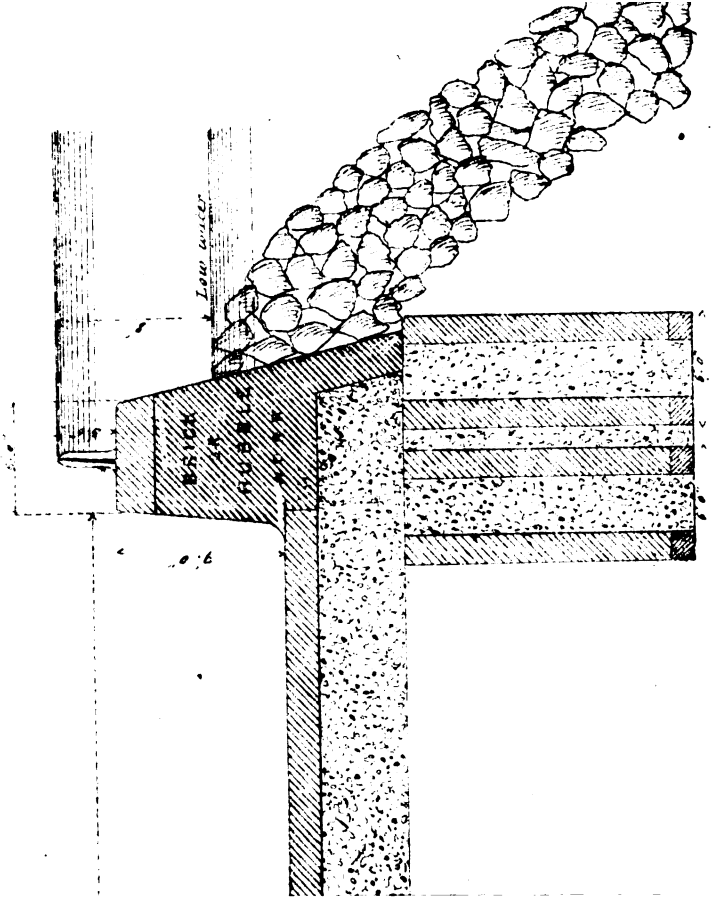
27. The Committee estimate the cost of the channel at nearly 68½ lakhs of rupees. An abstract of the cost of the different portions of it is given in the Appendix.

Form of weir for Ganges.

28. As regards the proposed weir across the Ganges a section has been proposed which assimilates to a considerable extent to that of the Godavery anicut. The form of overfall has however been changed. Sir A. Cotton has expressed his opinion on the subject in the following terms; after he had completed the Godavery anicut, "I must however say that here as in the Coleroon, I would now prefer building a work with a vertical fall as safer in sandy rivers; and so it would in any place excepting one similar to the Kistna, where there

Professional Papers, Madras Engineers, Vol. III., p. 169.





is unlimited supply of stone at very low rates, and where consequently 20 cubic yards of rough stone could be obtained at the same cost as one of cut stone. When I planned the Coleroon anicut, I considered that the great point in these rivers was to break the force of the water effectually, and prevent it scouring the lower channel; and what I have here seen makes me think still more of the importance of that principle. But I believe where stone can be obtained very cheaply, a large mass of rough stone with a very long slope 'on the lower side, will be the cheapest and safest work in a sandy river."

29. It will be observed that a depth of 15 feet has been allowed <sup>Depth of founda-
tions.</sup> for the well foundations. This depth though considerably in excess of that allowed in the Madras works, is about half what is generally considered necessary in the N. W. Provinces in the foundation of falls, and other works subjected to a scouring action. The plans of Madras anicuts, as at first constructed, do not show the works in their present state; for example, the rough stone in rear of the Godavery anicut extended in the first instance to a width of only 75 feet, now according to a section which the Committee have received from the Superintending Engineer of the division, it extends to a width varying from 120 to 150 feet. The anicut across the Kistna has also received considerable additions since it was first built, and large masses of rough stone have been thrown in along the front of the works, which do not appear in any plan. The Committee learn from Colonel Dyas, that several dams in Rohilkund have lately given way, owing to the want of a stone apron; vitrified lumps of kiln refuse, the only material available, having proved an altogether inefficient substitute.

30. In designing a weir across a river like the Ganges, the founda- <sup>Nature of action to
which a weir is sub-
jected.</sup> tions have to be secured against two distinct actions: firstly, the scouring action which is produced when the stream meets with an obstruction, and which would undermine and destroy the foundations, unless they are either carried down to the full depth to which the scouring extends, or unless they are protected by a mass of stone or other suitable material; and secondly the pressure arising from the water on the up-stream side of the weir being ponded up above the level of the water on the down-stream side. Unless the pressure is counteracted by the formation of the foundation wells or filling between them into a water-tight screen, it will force the water through between them, and by carrying with it the sand under the body of the work would cause it to subside and fall to pieces.

31. An instructive example of the scouring action is furnished in <sup>Example of scour-
ing action on the Go-
davery anicut.</sup> one of the Reports of the Godavery works. One of the sections of the anicut had not been carried completely across the channel, but for a distance of 260 yards an embankment and wing wall had been substituted. <sup>Professional Papers,
Madras Engineers,
Vol. III, p. 141.</sup> The course of the stream being obstructed by these works, and the only outlet for the water being over the anicut, a current was formed towards it along the face of the wing wall, and that of the

anicut itself. The result was the formation of a deep channel far below the bottom of the foundations, and a reference to the sections will show that the only thing that saved them was the deposition of a great mass of rough stone.*

Example of effect of hydraulic pressure on Coleroon anicut.

Professional Papers, Madras Engineers, Vol. I, p. 144.

32. As an example of the effect of hydraulic pressure, the Committee quote the following from a report by Colonel D. Sim, on the Coleroon anicuts. "This anicut was completed about the end of April, and was breached the following June during one of the freshes, about 80 yards of the northern division having been entirely destroyed; various causes have been assigned for the failure, and it is difficult at this time to ascertain which is the true one. It has been supposed by some to have been caused by a tall upright stone which had been fixed in the body of the work where the breach occurred, to indicate the height of the river in freshes, having got entangled in a quantity of straw and bushes floating down the stream, the large surface exposed by which acted upon by a powerful current tore it out of the anicut, and the water thereby getting access to the masonry which had not had sufficient time to set, easily destroyed the work. Others attributed the failure to the anicut having been undermined by the water being forced through its foundation by the heavy pressure during high freshes, and washing from under it the sand on which it rested. This appears to me the most probable cause of the failure of the lower anicut which was breached at the end of the second season, but I think the upper one could scarcely have been destroyed in that manner in the short period of a fortnight or three weeks. The water it is evident was forced under the foundation, and it was observed bubbling up in many places through the apron below, the anicuts whenever there were 5 or 6 feet standing above them, and if it passed in considerable quantities, which there is reason to believe it did, it would be very liable to wash away the sand by degrees and leave the work without support. During the last two years both anicuts have been materially strengthened by substantial aprons of cut stone in chunam being constructed behind them, to break the overfall of water, which have been executed in a very efficient manner. Since these additions the passage of the water underneath the foundation would seem to be considerably diminished, for it now spouts through the apron in only a few places and in small quantities, but I am not inclined to attribute this improvement so much to the aprons as to the large quantities of fine clay, and which has been collected in front of the anicut, and prevents the water being forced underneath them."

Protection against scouring action of the Ganges.

33. To apply the above facts to the case before the Committee, they have to remark that the length of the proposed weir, which for

* The Committee have been informed that the following large weirs at Madras have been breached at different times, viz :—Upper Coleroon anicut, in 1836 and 1859. Lower ditto, 1837, 1862, 1863, 1864, and 1865. Pennair anicut, 1858 and 1859. Vellaur anicut, 1853. Godavery anicut—(year unknown).

economical reasons has been limited to 4,000 feet, is only nine-sixteenths the width of the channel of the river during high floods. It is certain, therefore, that a scouring action similar to that above described as having occurred on the Godavery anicut, would be liable to be induced along the flanks of the work, and that they would require either a great depth of foundation or have to be protected in front by a large quantity of rough stone. To what depth the Ganges is liable to scour when it encounters such an obstruction as it would then meet with, there is no means of ascertaining; but it is known that the sand of which the bed and banks are formed is of a remarkably mobile quality, partaking in fact of the nature of quicksand, and that it is not unusual for the beds of the Himalayan rivers under conditions similar to those of the Ganges at Sookertal, to be scoured to a depth exceeding 20 feet below the ordinary level, when the stream sets against an exceptionally firm piece of bank. It may therefore be reasonably concluded that the foundation of a weir on the Ganges would require to be protected to a depth of at least 30 feet below the bed. It is proposed to allow 800 feet in length of wing walls for the up and down-stream sides together, on each flank of the weir, or 1,600 running feet in all; but in addition to this, the river would either have to be trained by means of rough stone groins for a considerable distance above the weir, or if defensive measures were confined to the embanked roadway which would have to be carried through the Khadir land, a large quantity of stone would have to be thrown in along the foot of its slope. It is impossible to judge precisely to what extent this protection would be necessary, but it is indispensable that precautions should be taken to resist the action of the river at any point against which the stream would be liable to set, and as this would be the case throughout the whole width of the Khadir, stone must be provided for the protection of the whole embankment. It would not necessarily be thrown in until the embankment should be threatened, but it would have to be collected at the spot ready for use at a moment's notice. The total length of bank to be thus protected would be $4\frac{1}{2}$ miles. For this it is proposed to provide stone of the section 30×7 for a length of one mile which would have to be divided over the whole $4\frac{1}{2}$ miles at such intervals as should in practice be found necessary.

34. As regards the undermining action generated by the simple pressure arising from the head of the waters on the weir, it is usual to puddle with clay in front and between the foundation walls to as great a depth as possible, but it would be difficult in the Ganges to work such material through the natural bed of semifluid silt, and it would be unsafe to wait until a scouring action should deepen the bed, before arrangements should be made for covering the front of the wells with a layer of clay. The actual process could hardly be arranged beforehand, but in one form or another it would be indispensable.

Protection against the action arising from hydraulic pressure.

Professional Papers,
Madras Engineers,
Vol. IV., p. 44.

The closing of the dam must also be a difficult and expensive process. Captain Orr, in one of his Reports on the Kistna anicut, mentions "the almost insufferable difficulties we met with in closing the Rallee branch of that river (Godavery), and the alarming doubt that for some time existed of our being able to so at all."

Summer discharge
of Godavery and Gan-
ges compared.

35. The discharge of the Godavery, according to Captain Haig, ranges from 3,750 cubic feet per second in February to 1,500 cubic feet in the first half of June. The discharge of the Ganges at the site of the proposed weir is 5,000 cubic feet per second. It is possible that when the Godavery anicut was closed there was an exceptionally high supply in the river; but the same contingency might occur with the Ganges.

Heavy contingen-
cies in constructing a
weir across the Gan-
ges.

36. In preparing an estimate for a weir, it may therefore be assumed that the expenditure on temporary embankments and in baling out water, and the losses occasioned by interruption of the works by unseasonable floods, and by the damage that would be produced by the floods passing over an unfinished work, would be very heavy; and that 50 per cent. would not be too large an addition to make to the rates at which the work (excepting cut stone) could be carried out for on dry land, free from all the drawbacks that have been mentioned.

Rates.

37. The ordinary rates are as follows:—Cut stone from Bhurt-pore, Rs. 2-8 per cubic foot; it is possible however that stone of suitable quality may be obtained from the Himalayas at Rs. 2, if the road from thence to Hurdwar, 16 miles in length, is made practicable for heavily laden carts. For rough stone, boulders might be used, but as they would have to be brought from some distance above Hurdwar, and as the carriage would be very costly, it will probably be advisable to use blocks of concrete instead. Any quantity of shingle can be obtained from the bed of the river 25 to 30 miles above the site of the proposed weir. It cannot be delivered at a lower rate than an equal quantity of brick, and allowing that the extra quantity of lime which would be used would be nearly an equivalent to the saving of bricklayers, it may be assumed without great risk of error that the concrete would cost much the same as brickwork, that is Rs. 20 for the commonest work.

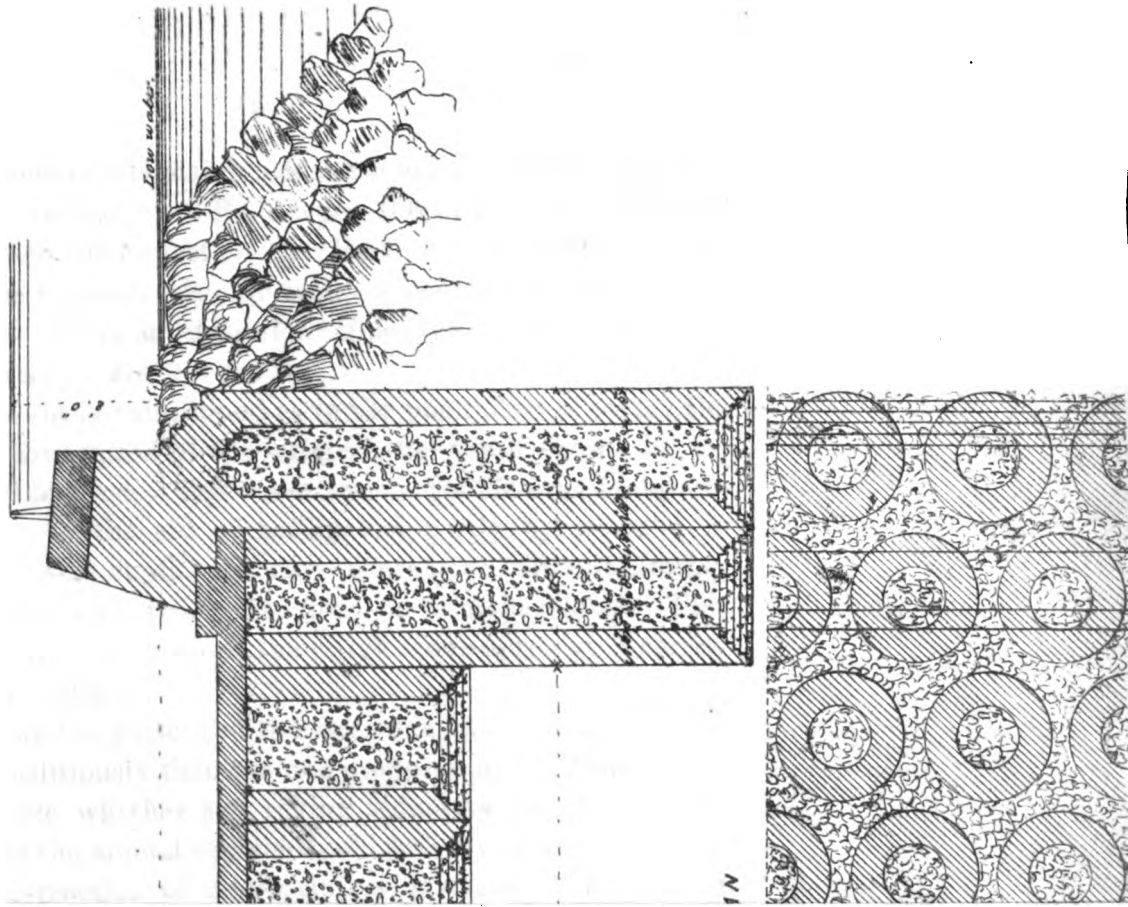
Estimate for weir
44 lakhs.

38. The estimate for the weir amounts to 44 lakhs of rupees. This may appear an inordinate amount compared with the cost of the large works of a similar kind which have been executed in the Madras Presidency, but the extra cost of the material of the Ganges weir serves in a great measure to explain the difference.

Compared with cost
of Anicut across Kist-
na at Bezwada.

Professional Papers,
Madras Engineers,
Vol. IV., p. 70.

39. The anicut across the Kistna at Bezwada, cost only Rs. 6,42,000, though a considerably larger amount of material was expended than has been provided for the Ganges weir. But at Bezwada there are inexhaustible quarries of easily worked but serviceable stone within 300 yards of the flanks of the work, and the



rough stone of which it was mainly constructed cost only 11 annas per cubic yard, or a fraction over Rs. 2-8 per 100 cubic feet. The cut stone cost Rs. 5, and the largest blocks Rs. 9 only, per cubic yard or from 3 to $5\frac{1}{2}$ annas per foot. Rough stone or concrete for the Ganges weir could not be delivered under eight times the Bezwada rate; or suitable cut stone under Rs. 2-8 per foot.

40. Some doubt is entertained as to the possibility of laying the concrete or brick foundation of the weir to the depth shown in the section, namely 10 feet below low water level. Should it be found unpracticable, partly by the aid of baling and partly by working in water, to attain to this depth, the only alternative, without altering the plan would be to construct the floor on a higher level. This would necessitate an extension of the rough stone apron at a corresponding additional outlay.

Proposed floor of Ganges weir might have to be constructed on a higher level.

41. A weir on the pattern of the Bezwada anicut could be constructed more expeditiously than the one proposed by the Committee, but it is questionable whether any saving would be effected in first construction, while the annual repairs would be very costly.

A rough stone weir could be more expeditiously constructed, but would not be less expensive.

42. The construction of under sluices at one or both flanks of weir must necessarily be a very expensive operation, as the whole of the floors would have to be founded on wells, and as the capacity of the sluices would not only have to be sufficient to discharge the ordinary supply of the river during the dry season, but the exceptionally high one, which is liable to be brought down in January and February.

Great cost of well foundations to under sluices.

43. In the above enquiry, the valuable experience which has been gained in the construction of weirs in the Madras Presidency has been kept in view, and the plan adopted for a weir on the Ganges, differs no further from those approved in Madras, than is considered necessary to meet the peculiarities of the Ganges, which have been previously described.

Experience gained in Madras kept in view by Committee.

44. One of the members of the Committee not satisfied as to the stability of the wells 15 feet in depth, or the feasibility of constructing the flooring from a level 10 feet below low water, has drawn out a section for a weir, on the principles which are generally followed in the N. W. Provinces, when 'a scouring action has to be provided against.

Suggestion by a member of the Committee.

45. The cost of a weir on this pattern would be much the same as that of the other, the extra cost of the wells being counterbalanced by the saving in rough stone.

Weir would cost much the same if well foundations were extended and rough stone reduced.

46. It is generally supposed, or by at least a large section of the Engineers in other parts of India, that the foundations of bridges and other works in the N. W. Provinces are extravagant, but in many places rough stone is so costly as to render deep well foundations the most economical procedure that could be pursued, for securing a work against the action of a powerful current.

Deep foundations less costly than rough stone in certain localities.

Cost of weir and channel together, 112½ lakhs.

47. The total cost of a weir across the Ganges, near Sookertal, and a channel from it to the present main line of canal to carry 5,000 cubic feet per second would thus be 112½ lakhs of rupees.

Compared with Major Crofton's project.

48. As Major Crofton's estimate for the rectification of the whole length of canal from Hurdwar to the head of the Cawnpore Branch, including compensation and loss of water-rents, if the canal were closed for a year, amounts to about 45½ lakhs, (Major Crofton's Report, p. 61,) it is evident that the Sookertal project cannot be recommended as a substitute.

Water in Ganges insufficient for full supply of canal at Hurdwar, and a separate canal at Sookertal.

49. When the additional works provided for by Major Crofton shall have been completed, the canal will be competent to carry the supply originally contemplated of 7,000 cubic feet per second. Now, as the Committee have before observed 5,000 cubic feet per second is the maximum* supply likely to be available at Sookertal, when an equal quantity is entering the canal at Hurdwar, there is not likely to be much above 3,000 cubic feet available when 7,000 are admitted at Hurdwar. In that event the great cost of a weir across the Ganges, which must be the same, whatever quantity might be taken from the river at Sookertal, would seem to render the consideration of a separate project for a head from that site superfluous.

Reference to Rajghat project.

50. The remarks however which have been made in the section of the Committee's Report relating to the proposed head from Rajghat, when a supply somewhat in excess of 3,000 cubic feet per second would probably be available, are applicable with slight modifications, to a project for conveying 3,000 cubic feet from Sookertal.

HEAD WORKS ON THE GANGES BELOW SOOKERTAL.

GURMUKTESUR.

51. The examination which the Committee made of the river at and about Gurmuktesur, led them to conclude that the site is unsuited for headworks; the great extent over which the river travels, the width of its bed, the unfavorable nature of its banks, combined with the scarcity of good building material in the neighbourhood, render it a most objectionable position for any such project.

RAJGHAT.

Best site for weir and head works.

52. The point on the Ganges which seems best adapted for the construction of the necessary works either for supplementing the lower part of the canal, or for supplying water for irrigating additional land on that part of the Doab, is in the neighbourhood of Raj-

* For the year 1864-65, the average supply admitted into the canal was 4,026 cubic feet per second. An observation taken at Gurmuktesur, 50 miles below Sookertal, on 5th February, 1865, makes the discharge of the Ganges only 4,278 cubic feet per second; total 8,304 cubic feet.



Water



clay available
in and from
cylinders are sunk.

ghat, nearly opposite Allyghur. The banks of the river and the adjoining land there, seemed to be sufficiently favorable for the purpose, to warrant such a survey of the locality as would supply details for estimating the cost of the work.

53. The Ganges canal plans, and the Trigonometrical Survey maps were first examined in order to ascertain the best trace to follow in the more detailed enquiry; the line was then levelled, a cross section and rough survey of the river made, and the discharge at low water measured. From these data the accompanying estimate has been drawn up.

Steps taken to collect information for estimating.

54. The construction of a weir across the Ganges at this site will be attended with similar difficulties and heavy expense as at Sookertal, nor can the examples of the Madras works be fairly applied to the case, for it cannot be too clearly explained that the difficulty and cost of such undertakings does not depend so much on the heights of the floods of a few weeks duration as on their long continuance, and on the volume and steadiness of the permanent stream, the nature of the bed and banks of the river, and the facilities of procuring materials, on all which points there are essential differences between the Godavery and the Ganges. The Committee—while careful to estimate the cost of the works as correctly as possible—are aware, that some degree of uncertainty must exist, and feel it their duty to guard against the necessity of further outlay except for *bonâ fide* repairs; the weir has therefore been designed with every regard to stability, and as much economy as circumstances will allow.

Difficulty of estimating cost of weir.

55. The quantity of flood water for which provision has been made is 300,000 cubic feet per second, that is 20,000 feet more than has been provided for at Sookertal—see note on that project. It is proposed to build the weir 4,500 feet long, to raise the low water level 8 feet, $5\frac{1}{2}$ by a masonry weir, and $2\frac{1}{2}$ feet by a moveable board, and the flood level about $1\frac{1}{2}$ feet; this height would be attained during very high floods only, and would not injure the low land to any important extent. There would be a velocity of about 12 feet per second over the weir in high floods.

Flood discharged and dimensions of weir.

56. The design for the work has been prepared with a view to using as far as possible the materials which are available in the district. It differs from the Sookertal weir so far, that the wells are designed to be sunk 30 feet below the bed of the river, and consequently, less protection of loose stone has been provided for. The most important of the local materials is the block kunker, it is found at a distance of about fourteen miles from the river; the cost in a rough state, delivered on the bank is about Rs. 10 per 100 cubic feet. Cut stone must be brought from Bhurtpore; the cost at Muthra is Rs. 1 per cubic foot, carriage from Muthra to Rajghat (a distance of about 80 miles) Rs. 1, dressing and setting, Rs. 0-8, a total of Rs. 2-8 per cubic foot.

Materials and their cost.

57. The extent and cost of training and protection walls and

Training and protection walls.

embankments is very uncertain; the right bank of the river is good and would therefore require very light works, but the left bank is subject to much erosion, and consequently would require heavy works and constant attention.

Water available in dry season.

58. The quantity of water passing Rajghat on the 10th April, 1866, when the Ganges was at a low level—some of the villagers said it was at its lowest for the year—was 5,630 cubic feet per second; while a measurement made at Cawnpore on the 5th of the same month, gave 5,438. The quantity for which provision is to be made in the new channel is 5,000 cubic feet per second, which is considered a fair quantity to fix for the purpose of this estimate; but it is tolerably certain that so much would not be available during very dry seasons with the canal taking its full supply from Hurdwar, while if a canal were to be opened from Sookertal to take off the whole supply of the river in the dry season at that point, the supply that would then be available at Rajghat would be very small.

Details of channel.

59. In fixing the dimensions of the channel the fall has been made as great as the nature of the soil permits, the object kept in view being to give as small a sectional area as possible through the deep cutting in the first twenty miles. By diminishing the slope and increasing the sectional area, the length of the line might be shortened; but the decrease in quantity by shortening, would be much more than counterbalanced by the additional width of excavation in the deep cutting. As the results of his enquiry, Major Crofton has adopted 2.5 feet per second as the highest velocity which the lightest of this kind of soil can stand, the same has been adopted here; consequently, the sectional area required to carry the quantity fixed upon is 2000 square feet. The depth of water to be carried has been fixed at 10 feet, and the side slopes of the channel at 2 to 1, with berms of 12 feet wide at 3 feet above high water.

Rate for excavation and cost of masonry works.

60. The rates for works have been fixed as nearly as possible in accordance with the prices now being paid in the district, making such additions for the great depth of cutting and consequent distance to which the spoil must be carried as were considered necessary. The number of bridges over the line has been estimated on the same principles as those by which the Ganges Canal Officers were guided; the rule being, that there should be a bridge at about every third mile. Very accurate estimates of the cost of crossing the small rivers, could not be made without waiting for detailed surveys and observations, which would cause much delay; they are, however, perhaps sufficiently accurate for a merely comparative estimate of this kind, the best information available having been collected from both Railway and Canal Officers.

Project cannot be substituted for Major Crofton's on account of cost.

61. The estimate for the work amounts to—

Channel,	..	..	..	..	..	..	67,54,550
Weir,	..	..	..	..	..	..	45,50,280
							113,04,830
Total,	..	..					113,04,830

this sum is for conveying 5,000 cubic feet of water per second from the Ganges to a point in the Cawnpore branch of the canal about 18 miles below the Naoon regulator. The whole cost of Major Crofton's scheme for remodelling the canal to carry the full supply down to this point does not amount to half this sum, it is therefore clear that the project cannot be recommended as a substitute in any way for his scheme.

62. As an independent scheme for supplying additional water for the irrigation of new ground in the lower part of the Doab, the cost of forming distributing channels and rajbuhas must be added to the estimate quoted above. The cost of the Cawnpore and Etawah branches of the Ganges canal, which pass about 3,500 cubic feet per second, will be about Rs. 29,00,000; taking the cost of passing 5,000 in the same proportion, the amount would be 42,00,000. The cost of the rajbuhas for the Ganges canal will be about 53,00,000, this is for distributing 6,750 cubic feet per second; supposing the cost of distributing 5,000 to be in the same proportion, the rajbuhas for the Rajghat project would be 37,00,000, making the total cost, say 1,92,00,000.

Project as an independent scheme.

63. The cost of the Ganges canal water is estimated by Major Crofton at 4,740 Rs. per cubic foot per second passed through the head works; this, however, includes the cost of navigation, for which a deduction of one-tenth may be made, making the cost for irrigation alone 4,260. The estimated cost per foot per second of the supply from Rajghat would be $\frac{192,00,000}{5000} = 3,840$ Rs. per cubic foot per second, so that the water would be a little less expensive than that of the Ganges canal.

Cost of Ganges canal water and of water from the Rajghat project compared.

64. The cost of clearing silt from a channel taken off from the Ganges at a point so low down as this, must be much greater than the cost of clearing a channel taken off at a point so near the hills as Hurdwar; but, on the other hand, this channel would be much shorter than the Hurdwar line, and consequently it would require less repairs and less establishment, and would not probably on the whole be more expensive to maintain.

Silt would be troublesome, but other annual expenses would be light.

65. Again, supposing the quantity of land which may be irrigated by each cubic foot per second to be 200 acres, a result now attained on the Jumna canal—and one hoped to be attained on the Ganges canal—and suppose the value of water to be Rs. 2-8 per acre, which is about the average rate now charged on the Ganges canal, and that the profits be taken at Rs. 1-8 per acre, those of the Ganges canal in 1863-64 being Rs. 1-6 out of Rs. 2-4; the result would be a profit of 8 per cent on the capital.

Return on capital.

66. It must however be remembered that 5,000 feet per second cannot always be relied on at Rajghat. If the Ganges canal were taking its full supply, that is about 3,000 feet per second more than

5,000 feet per second not always certain.

was entering at the time when the Ganges measurements above referred to were made, two-thirds of 5,000 would be fully much as could be calculated upon, while such a limited supply would continue the profits would be reduced to about 5 per cent.

Conclusion.

67. The Committee therefore conclude that the project can not be considered a reasonably profitable one to undertake at present; but it is not at all improbable that the value of water will rise, and that the quantity distributed per acre will be greatly reduced without any injury to the consumer, and if so, the project may be worthy of more careful examination at some future period.

HEAD WORKS ON THE JUMNA NEAR AGRA.

River near Agra.

68. The difference of level between low water at Agra and the high land is 61 feet, and the point at which water could be brought to the Etawah branch, allowing a fall on the channel of 6 inches per mile, is 116 miles from Agra, and within 27 miles of the termination of the branch. The Committee considered that on account of this great length of channel, and depth of cutting, and proximity to the termination of the present canal—beyond which are heavy drainages: further examination of that scheme was unnecessary.

NEAR DELHI.

River near Delhi—
site well suited for
head works.

69. The point on the Jumna which seems best adapted for head works, and for the formation of a channel to bring the water on to the land to be irrigated, is close to the village of Alee, about ten miles south of Delhi, and just opposite to the old fort of Toghluabad. The selection of this site involves the necessity of building weirs across both the Jumna and the Hindun, but after having examined the river at and below the point where the Hindun joins, and also at Alee, the Committee have no hesitation in recommending the latter as the best position for such works. The right bank of the river is remarkably firm and good, and the left bank is not particularly bad; but the strongest recommendative in favor of the site is the abundance of stone—both of rubble and of blocks, almost completely dressed, which can be obtained from the old fort, opposite to and within a distance of three miles of the river bank at Alee. Neither is the country on the left bank near the site unfavorable for the formation of a channel; the water could be brought into the Ganges canal below Baroli bridge, about the 115th mile from Hurdwar, or to the surface of the ground where irrigation might be commenced, without any great depth of cutting, and by a length of fifty-seven or fifty-eight miles of channel.

Flood discharge
Jumna and Hindun.

70. The information available regarding the flood discharge of the Jumna is even less than in the case of the Ganges; indeed there is

none to be found that can be safely relied upon. The railway engineers provided waterway of 2,400 feet in length at Delhi; but this has as much reference to the width of the river at that place as to the quantity of water to be passed through. An attempt has been made to calculate the discharge from a few isolated cross sections and the average fall, the results, however, have been so contradictory that they have been rejected as altogether untrustworthy, and it has been assumed that, as the heads of the rivers Ganges and Jumna are situated near each other, and almost similarly circumstanced as to sources of supply, the flood and dry weather discharges probably bear about the same proportion to each other in the two rivers. In the absence of better data, this mode of calculating has been adopted. The dry weather discharges of the Jumna is four-sevenths of that of the Ganges, the latter at Rajghat has been calculated at 300,000 cubic feet per second, four-sevenths of which or about 170,000, will be taken as the Jumna discharge. Regarding the Hindun, the railway engineers have provided a length of 440 feet of waterway across it, and as there is no better means of calculating the discharge it will be taken in the same proportion to that of the Jumna, as the waterway of the bridges bear to each other; this gives about 31,000 cubic feet per second as the flood discharge of the Hindun.

71. Several measurements of the low water discharge of both the Jumna and the Hindun have been made. The register of the height of the former river kept by the Executive Engineer of Canals residing at Delhi shows, that as a general rule the water is lowest in January; hence it is in that month that discharges are generally taken. Information on this subject has been kindly furnished by the Resident Engineer of the railway, which is to the effect that the water was as low in April last as it was in December; but as his own registry shows that the river was higher in April, and as he accounts for the rise shown by his gauge by assuming merely, that the damming up of the river by the bridge works at Delhi, caused a rise of the water level equal to that shown by his gauge, the Committee think that his information cannot well be relied upon; they prefer trusting to the readings of a gauge near Delhi, regularly kept by canal officers, and removed from the influence of any changes of level caused by the bridge works.

72. The dry season discharges of the Jumna at Delhi, and of the Hindun near its junction with the Jumna, were measured, as shown below and were found to be—

JUMNA AT DELHI.

				Cubic feet per second.
19th December, 1864.	Lieut. Moncrieff,	..	..	935
18th January, 1865.	Sergt. Caernarton,	..	..	1,613
19th December, 1865.	Mr. Garbett,	..	..	828
				<u>3)33,376</u>
	Average discharge,	..	..	1,125

G

HINDUN RIVER.

19th January, 1865.	Sergt. Caernarton,	..	..	..	357
18th ,, 1866.	Mr. Garbett,	..	..	..	501
					2,858
Average discharge, ..					429

making a total average low water discharge of the two rivers of 1,554 cubic feet per second, or say 1,500, which will be taken as the dry weather supply available for irrigation. It will be observed that this is above the observed minimum supply, but the very low discharge cannot be of long duration. The measurement made in April last, when the river was considered to be low, gave Jumna 2,800, Hindun 500 = 3,300. There are other measurements, which although not taken at Delhi, go to show that 1,500 cubic feet per second is not too low for an average minimum supply. Sir Proby Cautley, in page 43, of his Ganges Canal Report, Vol. I., makes the discharge at Agra 2,061 cubic feet per second; and Capt. Stewart made it 1,153, at the same place on the 19th January, 1865. Mr. Garbett made 5,004 at Delhi on the 19th January, 1866, but in the registry is noted "rain on the hills," which of course renders the result useless as a minimum guide.

Weir across Jumna.

73. The design of weir which is considered best adapted for the site is one in which the least quantity of brick-work and the greatest quantity of rough stone can be used, an abundance of the latter material being available at a very low rate. It is not considered sufficient to build the foundation of dry rough stone alone, the leakage through such a base, unless it were of very great width, would be considerable, if not even large, and the sand forming the bed of the river being very fine, would pass through with even a small leakage, the rough stone base would then sink, and the masonry floor, and probably the weir would be in great danger of breaking down. The form of section designed for Sookertal, has therefore been adopted, that is wells of moderate depth, protected by a large quantity of rough stone. The part of this report relating to Sookertal weir explains why such a section has been proposed there. It is proposed to raise the low water level 8 feet, 6 feet by a solid weir, and 2 by a moveable board. The length of the weir has been fixed at 2,500 feet, that being in about the same proportion to the length of the Rajghat weir, as the floods of the Jumna at Delhi bear to those of the Ganges at Rajghat. Such a weir would pass the calculated floods with an afflux of about one and a half feet, and with a velocity over the crest of about 11 feet per second, and without causing much injury to the low land above it.

Locks.

74. As the river navigation past the weir should be provided for, and as the proposed canal would be important as a line of navigation, two locks would be necessary, one to pass the weir, which should be 24 feet wide, to allow the largest river boats to be locked, and one to pass

through the canal, which as it is probable that through the canal entrance would be the best way of passing the river, may require to be of the same size.

75. The right bank of the river is good, consisting of very sound clay and kunker, the amount of protection required to it would therefore be very small; but the left bank is of the usual sandy loamy nature, and would require nearly the same class of works, to protect it, as provided for the Rajghat project. Protection of banks.

76. For crossing the Hindun and taking in its dry weather water, works similar to those used for passing the Rutmoo river in the Ganges canal would seem to answer very well, it is quite possible however that a more careful examination may show that great modifications would be found desirable; the Rutmoo plan is only adopted now as the best available guide in forming the estimate. The width of waterway provided by the Railway Engineers for their bridge over the Hindun must be sufficient for the passage required on the irrigation channel; they allow 440 feet. No lock has been provided for passing boats up, although it is not certain that one might not ultimately be required. Both banks of the river are easily eroded, and will require considerable protection. Crossing the Hindun.

77. As the cost of weirs across the Jumna and Hindun remains the same, whatever quantity of water may be taken off by channels in connexion with them, it may be more desirable to take an addition to the low water supply, when the river affords it, for the irrigation of a Khureef crop, than to trust to the dry weather supply alone; both views of the question will be briefly examined. It may be well to take water for a Khureef crop.

78. Probably the best rule to be guided by in fixing the quantity of water, above dry weather supply, which should be provided for in the new channel, is to make it as large as is consistent with keeping it navigable all the year round by the low water supply of 1,500 cubic feet per second. The lowest depth which is desirable for this purpose is about 6 feet, and the greatest depth in the channel may be limited to 10 feet, a maximum discharge of about 3,300 cubic feet per second will meet these conditions. Fixing the quantity of water to be taken for Khureef crops.

79. The highest velocity which the weakest of the soil through which the channels would be cut, could bear, is 2.5 feet per second, and a lower velocity than this would rapidly deposit the silt, carried by the rivers of this part of the country, 2.5 may therefore be taken as the velocity for the maximum discharge when the water would be the most heavily laden with silt. When the discharge falls to the dry weather supply, the velocity would be only about 2 feet per second; but then the water would be comparatively clear, and hence the decrease of velocity would be of little consequence. Velocity of water in new channel.

80. The sectional area of channel required to discharge 3,300 cubic feet per second, with a velocity of 2.5 feet per second, is 1,320 square feet, and the fall required is about five and a half inches per mile. As in the Ganges projects, it is proposed to have the bed of Capacity and length of channel.

the channel 2 feet under the present low water level of the river or 10 feet under the crest of the regulating board of the weir, and following the most favorable line of country, the water in the proposed canal could thus be brought to the surface in a distance of about 58 miles from the river,—passing through the low land of the Jumna and Hindun valleys for 19 miles, then through higher land in a cutting not exceeding 26 feet deep, and coming to the surface near the village of Baroli.

Rates and cost of project.

81. The rates for the earthwork have been taken from Major Crofton's estimate for the alternative line of canal, and the estimate for the masonry works required has been based on the same information; of course great accuracy is not professed, nor could it be attained without a detailed survey. The cost of this project would then be—

Weir and works on the Jumna and Hindun,	17,00,000
Channel, and all masonry works connected with it,	34,00,000
Total,	51,00,000

Cost of project if for dry weather supply only.

82. If instead of providing a supply for Khureef watering, provision be made for carrying the dry weather supply of 1,500 cubic feet per second only, a channel large enough to carry it, having the same fall of $5\frac{1}{2}$ inches per mile, and a depth of 10 feet, would give a velocity of 2.4 per second, which for the clear water of the dry weather would probably be enough; a sectional area of 50 feet bottom width, and side slopes of 2 to 1, would carry rather more than the required quantity. The cost of bridging and crossing small rivers would also be greatly diminished, but the weir works would remain the same. The cost of this project would be

Weir works, on the Jumna and Hindun,	17,00,000
Channel, including all masonry works, &c.,	18,65,791
Total,	35,65,791

This project was not meant as a substitute for the sanctioned work of remodelling.

83. It does not seem to have been contemplated either by Sir A. Cotton or by Government, that any work on the Jumna or on the lower part of the Ganges should have been in any way substituted for the present line of the Ganges canal; but it appears to the Committee that a few words may properly be introduced here on the subject before examining the Jumna work as an independent project.

Showing that it should not be substituted for the sanctioned work.

84. It is evident that aid from the Jumna, could only be substituted for the improvement of the Ganges canal, as sanctioned by Government, to the extent of the low water supply of that river. All the projection calculations, and all the calculations of the engineers who completed and worked the canal, are based on the supposition that it should have the full supply of 6,750 cubic feet per second during the whole dry season; an additional supply thrown in when the rivers would not be at their lowest, would not compensate in any way for the loss of water in January, when there is a large demand for the irrigation of the Rubbee crops, and when a continuous supply for them

is absolutely necessary. 1,500 feet per second is the full extent to which the Jumna at Dehli could afford aid, and consequently the supply to be received through the upper part of the canal could only be diminished by that quantity. Now, there can be very little room for doubt that the difference between the cost of improving the canal to carry 6,750 feet, and that of improving it to carry 5,250 feet would be small; if the Engineers should be obliged to turn off the water to carry out one project, they would certainly be obliged to turn it off to carry out the other, the difference of cost between the two works could not exceed twenty per cent., and it is not at all likely that it would amount to even so much. Major Crofton's estimate for remodelling down to Nanoon, is about 35,00,000, one-fifth of which, or 7,00,000, would be the probable gain by taking 1,500 feet from the Jumna, and 5,250 feet, instead of 6,750, from Hurdwar. But the cost of taking the 1,500 feet from the Jumna has been calculated at 35,50,000 rupees, so that the question of cost alone seems to the Committee to afford the most ample grounds for adhering to the project for remodelling.

85. But there are other reasons also. Adopting the Jumna scheme would be trusting to that which was not certain for that which may be considered tested and certain,—the feasibility of building and maintaining a weir across the Jumna is yet untried, and although there is no reasonable doubt but that it could be done, there is no certainty as to the time required to complete it, nor indeed as to the cost of the work. The quantity of silt which would be brought in by a head so low down the river is also an unsettled question, although known to be a very important one. Then there would be the evil of delay,—the Jumna project could not be undertaken without a careful examination, a detailed survey, and references for sanction; so that it would most likely be a year, or perhaps more, before any works could be commenced, and three or four years before they could be finished. And, lastly, although there is no appearance of immediate failure in the works of the canal, it is not at all certain that they would remain in a safe state for even one year; indeed, the Committee have recorded their opinion in another part of this Report, that it is of great importance that the repairs should be taken in hand as soon as possible. They have no hesitation whatever therefore in coming to the conclusion, that a new head from the Jumna cannot be substituted—either as a temporary or permanent arrangement—for the sanctioned project for remodelling.

Additional reasons why it should not be substituted for the sanctioned work.

86. If the work be adopted as a means of irrigating additional land, of which there is plenty available to the south-west, the cost of making distributing channels and rajbuhars must be added to the estimate given above; but on the other hand, the water would be brought to the surface of the land to be irrigated by channels at least 10 miles shorter than those required to bring it to the canal. Consider-

Project considered as a work for supplying water to irrigate additional land.

ing it first as a project for taking 3,300 feet per second when so much can be had, the shortening of the channels would lessen the expense of the main line by about 4,00,000 Rs. Then in order to make it complete as a navigation channel, the main line should be connected with the Ganges canal, this would require 10 miles of still water navigation at, say 15,000 a mile = 1,50,000. Making the total cost for weir and main channels 48,50,000.

The cost of distribution channels and rajbuhās for the Cawnpore and Etawah branches of the Ganges canal, which are to carry 3,250 feet per second, is—

Channels,	..	..	..	..	..	..	29,00,000
Rajbuhās,	..	..	..	..	..	..	9,50,000
							38,50,000
						Total,	.. .. .. 38,50,000

This estimate would give a fair idea of the cost of distributing the 3,300 feet from the Jumna, if the whole were to be used for a Rubbee supply; but as about half of it is for a Khureef supply, and as one foot per second used for Khureef, waters less than half the area which it would do if applied to Rubbee crops, it is evident that the distribution channels for a certain quantity of water used for Khureef watering, would be only about half the length of those required for the same quantity if used for Rubbee crops, and they would be only about two-thirds of the capacity. Now, as more than half the supply of the project under consideration is for Khureef watering, a deduction of about one-sixth may be made from the cost of the Cawnpore and Etawah branches, making the amount 38,50,000 – 4,83,000 = 33,67,000; which, added to the cost of main channels, give a total of 82,17,000.

Probable returns from capital.

87. The probable return from this outlay would be,—for Rubbee and Khureef crops, 1,500 cubic feet per second, at 200 acres per foot per second = 3,00,000 acres, at a profit of 1-8 per acre (see note on Rajghat project) = 4,50,000. Again using the Cawnpore and Etawah branches of the Ganges canal as a guide, it is found that each cubic foot per second, waters under 60 acres of Khureef crop: but it is probable that in this instance all the water is not utilized. The returns of the Eastern Jumna canals for 1863-64, give 7½ acres per foot per second as the quantity watered by the Khureef supply, using this as data, 1,800 cubic feet per second would water say 1,35,000 acres. The profit per acre would be about the same as that already calculated for Rubbee crops, giving a return of 2,00,000, and making a total on the whole outlay of 6,50,000, or a little under 8 per cent., exclusive of returns from navigation, plantations, &c.

Project considered as providing for a dry weather supply only.

88. If the project be confined to the use of the dry weather supply of 1,500 cubic feet per second only, the result would be,—cost of bringing the water from the Jumna to the Ganges canal, as

estimated above, 35,50,000; from which is to be deducted—cost of 10 miles of channel, by which the line would be shortened by delivering the water on the surface of the ground to be irrigated, 3,00,000, less the cost of 10 miles of navigation channel required to connect the irrigation channel with the Ganges canal, 1,50,000 = 35,50,000 – (3,00,000 – 1,50,000) = 34,00,000. The cost of distributing 1,610 cubic feet per second on the Cawnpore branch of the Ganges canal is 16,00,000, and the cost of rajbuhas for the same 5,50,000, making a total of 21,50,000. Taking the expenditure for distributing 1,500 to be in the same proportion, the cost would be 20,00,000 nearly, making the total cost 34,00,000 + 20,00,000 = 54,00,000. Using the calculation given above as to the value of the water, that is 1,500 cubic feet per second \times 200 acres per cubic foot \times 1½ Rs. per acre profit = 4,50,000 on an expenditure of 54,00,000; giving a return of about 8½ per cent., exclusive of returns from navigation, &c. From this it appears, that the project for taking in the dry weather supply only would be the more profitable. But further, the quantity of silt, which would be taken in by the Khureef supply when the river would be disturbed, and consequently muddy, would be very large, and without doubt must involve heavy additional expenditure for cleaning.

89. On the above grounds, the Committee are of opinion that the project for taking, either 1,500 cubic feet per second, or 3,300 cubic feet per second from the Jumna, is well worthy of a detailed examination, as an independent scheme for the irrigation of land in the lower part of the Doab.

Opinion of Committee.

90. They would, however, draw attention to the separate paper recorded by Mr. Sibley (Appendix A.), dissenting from the views of the majority, and advocating the formation of a canal from the Jumna at Toghluhabad, in substitution for Major Crofton's project.

Mr. Sibley dissents.

THE PRESENT CONDITION OF THE GANGES CANAL, WITH REMARKS ON ITS FAULTS AND UPON THE REMODELLING PROJECT.

91. So much has been said of the serious faults and inefficiency of this great work, that it has been a matter of some surprise to the Committee to find that it has been carrying nearly two-thirds of its full supply during the past twenty months; and that the navigation, though imperfect, has been going on without interruption during the same period, during which the canal has not been closed for even a single day.

Present condition of canal.

Full supply at Roorkee, 6,750. Supply maintained, 4,200 cubic feet per second.

92. The canal has now been in operation for eleven years, and though no outlay has been incurred for additional falls to lessen

Increase of irrigation, but velocity of current too great.

the slope and velocity of current which have been found to be much too great for the soil to bear, the area of irrigation has steadily increased.

Cannot be used to its fullest capabilities till fall works are increased.

93. Looked at as an irrigation work, for which it was principally intended, it has one very serious defect. The excessive slope of the country is not sufficiently overcome by artificial masonry falls; and, consequently, as already mentioned, the velocity of current is too great. The canal cannot therefore be used to its fullest capabilities till the fall works are increased.

Navigation impeded by velocity of current.

94. Viewed with regard to navigation the velocity of current is a great obstacle to traffic. The want of sufficient headway under bridges on the Cawnpore Branch is also a serious disadvantage, as in carrying light and bulky cargo, boats are loaded to a great height above their decks. The insufficiency of headway is the more unfortunate, as it would not have added much to the original cost of the works to have given 10 feet, as in all the large bridges on the main line.

Imperfection of arrangements in regulating passage of water at falls.

95. The excessive velocity of current appears to have been further increased by an imperfection in the arrangement for regulating the flow of water over the falls. They were originally designed of greater width than the earthen channel, and in several separate chambers or compartments, the entrances to which were fitted with sleepers to admit of their being closed for repairs. But when the canal was first brought into operation, and all the works were new and in good repair, the stream was permitted to pass through all the compartments, and its velocity as it approached the falls was thus accelerated. No evil would have resulted from this if the soil had been firm, but it was too soft to bear the rapid current.

Delay in applying remedy.

96. The canal authorities do not appear to have been fully aware till too late that the current was so much too rapid, and that it was steadily working upon the bed, and causing a retrogression of levels below each set of falls. What principally engrossed attention at first was the construction of minor distributing channels, and especially the arrangements for giving the water to the cultivators by measurement, the importance of which was certainly not over estimated. The canal, moreover, had only been in operation two years, when the district which it traversed became the scene of the mutinies, and Europeans of all ranks were compelled to leave their ordinary duties. The mutinies, and the unsettled state of affairs which immediately followed, were hardly over when this same part of the country was stricken with famine, and the whole attention of the canal department was given to distributing the water to tide over the calamity; minor channels were pushed on in every direction with the utmost possible rapidity, and as much water as could be distributed was thrown into the canal.

97. Thus great delay occurred in reducing the waterway at the

falls; and when at length the urgent necessity of doing so became apparent, further delay occurred in carrying the necessary arrangement into effect, from the sleepers, which are 25 feet in length, giving way.

It was not till 1862 that the waterway was effectually reduced, and by that time so much retrogression of level had taken place that it became impossible to apply means, which at an earlier stage would have been feasible. Whether at first it would have been quite safe to have completely closed several of the fall compartments, and have passed the water through the remainder with an increased depth, cannot now be decided; but there is no doubt that by delay the cushion of water on the floorings had become so much reduced that such a plan could not be attempted, and the expedient was adopted of partially closing all the compartments and distributing the water equally over them. This arrangement however in obviating one difficulty led to another. The water instead of gliding over the ogee descent in the manner intended, fell suddenly upon it from an increased height, and exposed the masonry to an action it was never designed to bear.

The delay increased the difficulty of applying a remedy.

98. The parts of the works which suffered most from the retrogression of levels were the floorings under the falls. The water now fell from an increased height upon the masonry itself instead of into a cushion of water, and the action thus intensified tore up the brickwork wherever it happened not to be of the very best quality, as was the case at the Mahmudpoor, and some other falls below Roorkee. Above Roorkee, as well as in other parts of the canal, the brickwork, though requiring occasional repair, has not suffered seriously.

Injury to the works from severe action of water.

99. Another evil which the retrogression of level caused was the greatly increased velocity with which the water escaped from the floorings into the earthen section of the canal below. Instead of flowing off with a moderate velocity, it made a rapid shoot and scooped deep holes in the soft soil where the protective boulder crib work terminated, an effect which was increased by the direction given to the wing walls at some of the falls. Thus the whole of the masonry work was endangered. An accident was only prevented by the crib work with which the foundations had been protected, and which accommodated itself to the change in the level of the canal bed without permitting the foundations to be completely exposed.

100. Various expedients were adopted by the canal officers to mitigate the evils caused by the retrogression of levels. Small rough supplementary weirs were thrown across the floorings to hold up the water and thus obtain a "cushion" under the falls, and other rough weirs were carried across the canal at a distance of about 100 yards below the tails of the floorings, to head up the water and diminish the plunge over the crib work into the soil excavation. None of this work was of a permanent character, but it has enabled the canal officers to keep the canal steadily running with two-thirds of its full supply.

Expedients adopted to remedy evil of retrogression of levels.

Injury to road bridges prevented by protecting foundations with boulders.

101. At the road bridges also the retrogression had an injurious effect, but this was remedied partly by the crib work with which their floorings had been originally protected, and partly by adding loose boulders.

Expedients adopted prevented further serious damage, but retrogression not altogether arrested.

102. Since these expedients were adopted there has been no further serious damage, and the deep holes which had been formed near the masonry works have to some extent silted up; but that retrogression is still going on, was evidenced by the state of the water at different points along the canal at the time the Committee examined it. This view is concurred in by Colonel Dyas, who in reply to a question from the Committee, writes as follows:—

“As to the bed (of the canal) erosion is no doubt going on in many places, inasmuch as during the cold weather, when the water coming in from the Ganges river through the Myapoor regulator (the head of the canal) is almost quite clear, the water in the canal gradually becomes very muddy. But a comparison of cross sections of the canal bed, which I have lately had taken at every mile along the canal, with similar sections taken by Major Crofton in 1864, shows that no dangerous action is going on at present.”

Falls still exposed to most violent action.

103. The falls, moreover, notwithstanding all the expedients that have been applied, are still exposed to a most violent action, which the brickwork was not designed to bear, and it is impossible to predicate how soon some accident may necessitate the sudden closing of the canal and the destruction of the crops dependent upon it. The Committee were anxious to have had the canal laid dry to enable them to closely examine the masonry works, but such strong objections were urged against it by the canal officers, on account of the time it would occupy and the injury to crops which required constant watering, but more especially on account of the injury which might be caused to the floorings of the falls when the depth was reduced, both when shutting off the water and re-admitting it again, that the point was not pressed. With respect to the condition of these works, Colonel Dyas replied to the Committee as follows:—

“As to the falls in the Northern division (from Myapoor to Jaoli) the extent of damage done (during the past twenty months), as far as can be ascertained by careful sounding and probing, consists of a slight displacement of crib work battens. In the Meerut division two falls have been slightly injured, but not sufficiently so to warrant a closure of the canal for the purpose of repairing them. The Chitoura fall (55 miles 4976 feet) has had part of the ogee in No. 3 bay ripped out, and that bay is kept closed in consequence, to prevent further damage; and the Sulawur fall (67 miles 2350 feet), has had two of the hammer-dressed Delhi stones in flooring of No. 3 bay, lifted out and turned over. This occurred in September 1864, and the stones have not moved since. The bridges are all secure.” Colonel Dyas’ report is on the whole a favorable one; but it is evident

to the Committee, as it is to all the canal officers, that the falls are still in danger, and that no time should be lost in taking steps to render them secure.

104. The navigation on the Ganges canal has always been necessarily imperfect from the great velocity of current which in the main canal was intended to be from $2\frac{1}{2}$ to $2\frac{3}{4}$ miles per hour; and in addition to this obstacle the retrogression of levels, and the consequent necessity for limiting the depth of water admitted into the canal has acted most injuriously. The lock channels, instead of having a depth of 9 or 10 feet of water in them, and a width at water line of 43 to 46 feet, have had barely enough water below the locks to float boats of light draught, and a width at water line of only about 28 feet, the width at bottom being 16 feet. This very limited capacity of channel has of course delayed the introduction of large boats, and has led to frequent interruption when silt accumulated. The shortness of water supply in the canal moreover necessitated the alternate closing of the Cawnpore and Etawah branches to distribute the water for irrigation, and thus the navigation on the former which connects the main canal with the river Ganges has occasionally been completely closed. Under all these circumstances it is not surprising that the navigation has not increased satisfactorily.

105. The Committee may remark here that the present lock channels would probably work efficiently if the eroding action of the stream in the main canal were less, and if the valves at the locks were larger to admit of more effectual scouring. But where new locks have to be constructed, they think that attaching them to the falls, as in Major Crofton's project, is a great improvement.

REMARKS ON THE REMODELLING PROJECT.

106. In correcting the great fault of the canal, or "remodelling" it as it has been termed, an expression which however is apt to lead to a somewhat erroneous impression of the measures required, the Committee remark that while on a work like this, of almost a national character, they would not expect to see such rigid restriction of expenditure to works of absolute necessity as is generally practised in the construction of ordinary irrigation canals, yet at the same time, considering how important it is both for the reputation of the Ganges canal itself, as well as for the interests of other large irrigation projects in other parts of India (whose execution is supposed to be delayed on account of uncertainty as to their financial success), that economy as well as efficiency should be studied, they cannot but regard some of the changes provided in the remodelling project as unnecessarily expensive, and they would therefore suggest that the following points be carefully reconsidered:—

The present shape of the cross section need not be altered, and requisite capacity to be obtained by raising crests of falls.

107. *The Excavation.*—It appears that the effect of the retrogression of levels has been to deepen the canal in the reaches between each set of falls, and in the remodelling it is proposed to alter the shape of the section by widening it and filling in the bed where material is furnished from the widening, and trusting to the deep spots ~~settling up~~ where material for filling is not available. Now, however desirable it would be in designing a new work to adopt a shallower section, it can hardly be necessary to alter an existing work to give it that precise form. The cost of the excavation from the head of the canal to Jaoli falls is estimated at upwards of four lakhs of rupees, and it is apparent to the Committee that by slightly raising each set of falls, so as to reduce the surface slope by about one inch per mile, the present excavation will generally answer, and a considerable outlay will be saved.

Grating at Kunkul bridge objectionable, and lock unnecessary.

108. *Grating and lock at Kunkul bridge.*—These are estimated over Rs. 30,000, and may well be omitted. The sunken grating in almost a perpendicular position seems to be actually objectionable, and the lock with its attendant working expenses, can hardly be required to meet the contingency of a boat passing up the stream at a time when there might be only a small supply of water in the canal. It will always be necessary to maintain a large volume in the canal, and supposing a boat to arrive at Kunkul, when there might accidentally happen to be a small supply, the acceleration of the current at the bridge could be checked by partially closing the compartments of the falls three miles below, especially if instead of giving the bed of the canal a sudden drop below the bridge, the change from the small to the large section be made gradual.

New fall and lock at Roorkee may be dispensed with. Objection to increasing depth of water on Solani aqueduct.

Protection of canal bed.

109. *New fall and lock at Roorkee.*—It appears to the Committee that by pitching the bed of the Solani aqueduct (earthen portion) and securing the floorings of the bridges at Rutmoo, Peeran Kullier and Mahewar, the new fall and lock may be dispensed with, and some reduction in the expense effected. But they also object to the proposed falls on other grounds. The Solani aqueduct was designed to carry a stream 10 feet in depth and if the falls are constructed this will be increased to nearly 13 feet. The Committee do not doubt that the aqueduct can be made to carry the increased depth, but sufficient provision is not made in the estimate for this, and as the expense will be heavy to render the work perfectly secure from accident, and there is already percolation through the brickwork of the masonry aqueduct which must in time do harm, they would prefer retaining the designed depth of water in place of increasing it to nearly 13 feet.

Reduction of slope below aqueduct to be effected by raising Asuffnugger falls.

110. With respect to the reduction of the velocity of current from the aqueduct down to the Asuffnugger falls, it will be necessary to raise those falls slightly; but this will not be attended with any difficulty, and it will have the effect of saving a large quantity of excavation in the manner indicated in a previous paragraph.

111. *Additional arch to increase the waterway under bridges.*— Additional arch to bridges not absolutely necessary.
 This does not appear to be absolutely necessary. All the bridges have already been subjected to a very severe test from the retrogression of levels, and the boulder protection to the floorings has been increased. When the floorings are lowered to suit the altered bed level of the canal, the waterway will be increased, and the velocity of current will not, the Committee consider, be too great. If the wide section proposed in the remodelling be adopted, the omission of the additional arch will only increase the velocity from $1\frac{1}{2}$ to $2\frac{1}{4}$ miles per hour, and this only for a few yards. If the deeper section recommended in para. 107 of this Report, be adopted, the increase of velocity will be even less.

112. Before leaving the subject of the works provided in the remodelling estimate, the Committee would make some observations on the question of closing the canal for a long period to admit of the works being executed. In Major Crofton's report the estimate of loss from closure amounts to Rs. 13,48,213; but owing to the extension of the irrigation since that estimate was made, and to the increase in the water-rate levied, it appears that the loss from a long closure now would probably amount to upwards of twenty lakhs of rupees. Large loss of revenue from closing the canal for a year, and modification of floorings under falls suggested.

The Committee are sanguine, however, that the works can be executed without a long closure, especially if the details of the floorings of the new falls are modified. With the view of obtaining a deeper cushion of water over the floorings, Major Crofton has placed them at about 4 feet below the bed of the canal, and at this depth a covering of brick-on-edge is considered by him sufficient to resist the action of the water. The advantage of the deep cushion is probably not over-rated, but placing the flooring at so low a level will cause great delay for unwatering or forming cofferdams, and as the loss from long closure will be very heavy, the Committee would recommend that the deep cistern be omitted, and that the flooring be placed at the level of the canal bed, and covered with Bhurtpore dressed stone, 15 inches in thickness; and they would remark that, though the stone is very expensive, there is this great advantage in the arrangement that, whenever repairs may be required to a flooring placed at the level of the bed of the canal, they can be readily executed, because directly the canal's supply is shut off the floorings would be exposed to view. With the aid of the gratings which the Committee understand Colonel Dyas has contrived with complete success on the Barea Doab canal, for breaking the water as it begins to fall, the Committee consider that the modification they recommend will be found to answer well.

113. Supposing that the works can be executed during two short closures of about $3\frac{1}{2}$ months each, the loss of revenue would be comparatively trifling. Comparatively small loss from short closures. From information furnished by Colonel Dyas,

the Committee have approximately* estimated it at Rs. 350,000 for each closure, on the supposition that the crops which must be stopped are not replaced by others which can be watered at some other period of the year when there is an abundant supply in the canal. If other crops be substituted, the loss during each closure would only amount to about Rs. 150,000.†

114. The Committee believe that two such closures will be found sufficient to complete all the work up to water line, and they would point to the cases of the upper and lower Coleroon anicuts, and the Gunnarum aqueduct in Southern India,‡ each of which was commenced and completed in one dry season, as instances of what may be done in speedily executing hydraulic works.

Future improve-
ments.

115. The Committee would now draw attention to some points affecting both the navigation and irrigation which seem to call for consideration as measures of future improvement.

Large proportion of
artificial to natural
flow irrigation on the
Cawnpore and Eta-
wah branches.

116. *The large proportion of "artificial" § to "natural flow" || irrigation on the Cawnpore and Etawah branches.*—There is a considerable loss of revenue on this account on the two branches, but whether this is caused by the smallness of the supply of water which keeps the surface at too low a level; by the levels of the country being unfavorable for the cross distributing channels; by a faulty alignment of those channels; or from the excavation of the canals themselves being unnecessarily deep; the Committee have not ascertained. A great part of the Cawnpore branch appears to be in light excavation. The Etawah branch¶ is generally deeper. The cross channels or rajbuhars are said to be badly laid out, and to work very imperfectly. However this may be the subject demands careful attention, and if it should be found necessary to introduce weirs at intervals to bring the water up to a higher level at certain spots, it would be desirable to make allowance for such alterations in level where the headway under the bridges is increased for navigation, otherwise it may be necessary to alter the bridges a second time. The introduction of weirs would be advantageous as affording the means of more efficiently controlling and distributing the water on

* The Committee applied to Colonel Dyas for an estimate of the loss, but have been disappointed in not receiving it. Since the Committees' Report was drawn out, Colonel Dyas has written demi-officially as follows :—"I have been disappointed about the information I wrote for to enable me to estimate the loss that would be incurred by closing the canal in March, April and May, and I fear when it does come it will be too late to be of use to the Committee, so I think you had better go upon the estimate you drew up, and which is founded on the latest information I have. I should be very much obliged by your sending me a copy of it. I will write again if the information I have written for comes soon; but don't wait for it."

† The Committee observe, *vide* Revenue Report, dated 4th March, 1864, that the loss sustained during a three months closure in 1862-63, amounted to Rs. 2,25,689. The closure was necessitated by an injury to one of the falls, and took place at an unfortunate period of the year, while the Rubbee irrigation was at its height.

‡ All of these works are on well foundations.

§ Artificial, *i. e.*, aided by machinery.

|| Natural flow, *i. e.*, by gravitation.

¶ Average depth of excavation in Cawnpore branch is 4.82 feet for the first 120 miles; average depth in Etawah branch for the same length is 6.65 feet. The water is 6 feet deep in both cases.

these long branch lines, and would also benefit the navigation by reducing the velocity of current. These are additional reasons for an investigation of the question by the canal officers. It may be found possible to improve the irrigation by extending the distributing channels till they command more low land.

117. *Want of sufficient waterway at terminus of Cawnpore branch.*—This branch is too narrow near its terminus to allow of the largest class of boats passing each other, but this may easily be corrected by enlarging the canal from 20 to 27 feet bottom width from the 159th mile, and making it still water navigation from the 164th mile to Cawnpore, a distance of $5\frac{1}{2}$ miles; arrangements will of course be necessary at the commencement of the still water canal to lead off for irrigation the volume of water which is brought down to that spot by the flowing canal. The silting and growth of weeds which are likely to occur in the still water must be accepted as unavoidable, but as the length is short there will be no serious difficulty in maintaining the canal in good order.

Cawnpore branch to be enlarged at its terminus.

118. *The Etawah branch.*—The headway under bridges on this branch is insufficient and should be increased, the tail should be locked down to the Jumna with still water navigation, arranged as recommended for the Cawnpore branch.

Etawah branch to have its navigation improved as recommended for Cawnpore branch.

119. *Cross canals for navigation.*—At present boats have to make a long circuit to get across from one canal to another, this should be provided for by constructing short cross lines; similar lines should also be formed to connect important places like Meerut, Bulundshuhr, Coel, &c., with the main lines, as the requirements of trade may indicate.

Short cross canals for navigation to connect main canals with each other, and with important towns.

120. *The width of locks.*—This question seems to demand some remark from the Committee, as it has been proposed to go to some expense to obtain 20 feet in width. The existing locks are 16 wide, and after careful discussion the conclusion arrived at is, that this dimension is sufficient. The depth of water generally in the canal is so great that there could be no objection to the use of screw propellers if steam navigation should appear profitable: the stern wheel also could be used. Moreover, locks of 20 feet width would still be too small for side paddle steamers except of a very small class.

Width of lock 16 feet considered sufficient.

121. *New branch canal from Roorkee to Deobund.*—The construction of this work has been under consideration for some years, but the shortness of supply in the main canal has of course hitherto kept it in abeyance. In Colonel Turnbull's Canal Revenue Report of 1861-62, Mr. Login's opinion on the result of the survey is mentioned as most favorable. The Committee have also received the opinion of Mr. Williams, the Commissioner of Meerut, who strongly advocates the carrying out of the project for protecting the district through which it will pass, against famine, and for more equally distributing the benefit of canal irrigation throughout the country,

Branch canal for irrigation from Roorkee to Deobund recommended.

the Deobund district being most unfortunately circumstanced as regards water, which is only obtainable at present from very deep wells. The line which this branch will follow corresponds with that recommended by Sir Proby Cautley as the alternative line, and the Committee think that the time has arrived for turning attention to it.

Short periodical closure of canal recommended for examination and repair of works.

122. *Periodical closure of canal.*—In so large a work dependent on many masonry structures of a difficult nature, a short annual closure would be desirable to admit of everything being closely examined, and repaired if necessary. The canal officers will of course be able to decide upon the best period for such closures, as they know during which portion of the season the demand for water is least. If the plan of making a periodical closure is carried out, the cultivators will probably soon learn to store a small quantity of water near their fields to continue the irrigation till the canal is re-opened.

PROPOSED WEIR ACROSS THE GANGES AT HURDWAR.

Importance of a permanent weir at Hurdwar generally recognized.

123. The importance of gaining a control over the Ganges at Hurdwar by means of a masonry weir across the channel has been generally recognized. There is no difficulty however in throwing in the supply at present required by the canal, namely 5,000 cubic feet per second, and the expense has not increased to the extent that was anticipated by the late Colonel Turnbull. During the last four years the outlay incurred on the shingle bunds, or temporary dams, for diverting the supply from the river to the canal has amounted to 60,702, or 15,175 rupees per annum.

Not however necessary for the present supply of the canal.

124. If 5,000 cubic feet per second were to be the full supply of the canal, the Committee would not advocate the construction of a permanent weir across the Ganges. The expense of keeping such a work in repair would not certainly be less than 5,000 rupees per annum; 10,175 rupees would therefore be saved in maintenance, and allowing even that the expense of raising the bunds should increase so as to make the saving 15,000 rupees per annum, this would represent a capital of Rs. 300,000, and a permanent weir across the Ganges could not be built for that amount.

Temporary bunds rarely necessary during monsoon months.

125. It is true that although there is no difficulty in throwing 5,000 cubic feet per second into the canal during the dry season, there is the possibility of the river falling so low during some of the rainy months, as to render it necessary to have recourse to bunds even at that season; which was the case during the famine year of 1860-61, and the inefficiency of the temporary arrangements during the monsoon months, has afforded the strongest argument that has hitherto been brought forward for the construction of permanent works.

126. But the Executive Officers have now a much more extended experience of the management of the river, than they had up to the famine year; and the Committee consider that with the good management which may be expected, there ought to be no difficulty in feeding the canal during the monsoon. They believe that the failure during the famine year has been exaggerated. For a great part of that year, the whole supply of the river was turned into the canal, and the revenue returns were more than double those of the previous year; but the fact of 73 acres only having been irrigated per cubic foot of water admitted into the canal, while at present upwards of 140 are irrigated by the same quantity, indicates that the great want of the famine year, so far as the canal was concerned, was the means of distributing the water. The rajbhas were then in their infancy, and without a proper proportion of them, it would have been useless to increase the supply from the river.

Experience of Executive Officers equal to such a contingency.

127. When the full supply of 7,000 cubic feet per second has to be thrown into the canal, the construction of a weir becomes more necessary than with a supply of 5,000 cubic feet. Sir Proby Cautley's estimate of the minimum discharge of the Ganges is over-rated; at times it falls considerably below 7,000 cubic feet per second. With shingle bunds there must always be considerable leakage, and at such times, the loss thereby occasioned might seriously affect the efficiency of the canal. The Committee look upon this as the most important argument in favor of a masonry weir, but they may add that it is very desirable that both Europeans and Natives should be saved from the exposure and sickness which they have to undergo in the construction of the temporary bunds during the most unhealthy time of the year.

With full supply in canal considerable loss of water by leakage through temporary bunds, and masonry weir necessary.

128. Several projects for a weir have already been before Government, but none of them have met with acceptance. Colonel Dyas was about to enter upon the subject, and was having detailed surveys prepared, when the Committee was ordered to assemble; but not knowing that the question of a weir at Hurdwar would occupy their attention, he removed the officer who was surveying there to employ him on a survey of the Khadir land between Sookertal and Gurmuktesur; some further measurements are therefore required before Colonel Dyas can submit a plan and estimate for a weir to Government. The Committee are not prepared to furnish a detailed plan, which would require a more comprehensive knowledge of the locality than they have had the means of acquiring.

Design for weir left to Colonel Dyas.

Observations on matters of secondary importance.

129. Having in the foregoing Reports stated their views and opinions on the principal points connected with the subject referred to them, the Committee proceed to offer some observations on matters, which, though of secondary importance, will not, they trust, be considered irrelevant to the complete elucidation of the state and prospects of the Ganges canal.

STONE FROM THE SEWALIK HILLS AND HIMALAYAS FOR THE CANAL WORKS.

Good stone only procurable in small quantities from different places in the Sewalik hills, and the search for stone in the Himalayas hitherto unsatisfactory.

130. With respect to the use of stone from the Sewalik hills at Hurdwar, and elsewhere on the canal, the Committee having made the most careful enquiries, and to some extent, inspection of the localities, are satisfied that although stone of good quality may be obtained in small quantities scattered over the hills, yet there is apparently no single spot where quarries can be opened with the prospect of an abundant supply being met with, and that as regards the main Himalayas, they find that the search for stone has hitherto proved equally unsatisfactory in its result.

Further and more extended search recommended.

131. The Committee are however convinced that the canal officers have used their best endeavors to obtain stone of suitable quality for the works, and beg to refer to the following replies from the Chief Engineer of Irrigation to queries put by them on the subject. They however think that the search on the main Himalayas should be extended when the weather will admit of its being done more carefully than it could be at this season; and also that a quarry on a more extended scale than any which the Committee have seen should be opened at Hurdwar.

Reply to Committee's enquiry.

132. Replies to questions in Colonel Lawford's letter of yesterday.

Question 1.—"What was the result of the search made for stone at Hurdwar and in the Sewaliks in the neighbourhood, stating cost of

"Quarrying,
"Dressing,
"Leading to canals,
"Making roads,
"Superintendence."

Reply.—The report made in para. 13 of my letter 4,293, dated 23rd November, 1864, which was printed with Captain Crofton's Report on the Ganges canal is correct, viz.: "The quantity of serviceable stone to be had at any one place is very small, and there are not very

many places within easy reach of the works or of water carriage where it can be had.

“The places where fair stone was found were soon worked out, and operations had to be closed on the 31st August, 1865, when 51,496 cubic feet of stone had been landed, at a cost of 51,455 rupees, say one cubic foot per rupee.

“The following is a tolerably accurate approximation to the details of cost:—

	RS.	A.	P.
“ Quarry and leading to carts,	0	3	6
Dressing,	0	3	0
Leading to canal, with loading and unloading,	0	5	6
Making roads,	0	2	0
Establishment and tools,	0	2	0
Total per cubic foot, rupees,	1	0	0

“The stone is of very unequal quality and very uncertain; thus, part of the same block may be good hard stone and the rest so friable that it can be rubbed into sand with the fingers. The particles of sand are held together merely by infiltration of lime which partially dissolves in water, so that, after 60 hours' immersion the stone will bear only half the crushing weight which it will bear when dry.

“Dividing the stone landed into three classes—fair, middling and bad—I find that the crushing weight of each in lbs. per square inch, was as follows:—

Class.	Dry.	Wet.
Fair,	5,811	2,764
Middling,	5,356	1,879
Bad,	3,003	1,447

“The following is the result of similar experiments on our bricks.

Class.	Dry.	Wet.
	lbs.	lbs.
Best,	3,000	3,000
Seconds,	1,932	1,288

“The crushing weight for jamah, wet or dry, is 6,180, and for Dehli quartzite, 16,480.”

I have already shown the details of these experiments, and the crushed specimens themselves to (I think) all the Members of the Committee.

Question 2.—“ Has any search been made for stone in the main Himalayas in the neighbourhood of Luchmun Jhoola, or elsewhere, and if so the result ?”

Reply.—“ There are now no European officers here who can give information concerning matters of ancient date, nor have I been able to find in the records of this office any report of explorations made beyond the Sewaliks. But I have ascertained from the old mistrees employed on the works that the country up to and beyond Luchmun Jhoola was often in vain explored for stone. In 1862, Professor H. B. Medlicott was employed in exploring, with Mr. Login, but I can find no other report of his than may be gathered from the printed memoirs of the Geological Survey of India, Vol. III., Part 2.

“ Lately, at my request, Mr. Kelly has examined the valley of the Ganges and the streams which run into it on both sides as far as the stream above Tupobun, but he has not found anything worth quarrying. He reports that the sandstone about Rikheekes is much the same as the sandstone of the Sewaliks, that the black shale which underlies the limestone is in thin layers, that the limestone itself flies to pieces under the hammer, and that the slate is only to be had in small thin pieces.

“ On Mr. Kelly's return with this report I requested him to offer a liberal reward to any one who would point out a place where good hard stone was to be had *in situ*, and he has men employed in exploring. He is now in all probability before the Committee, as I requested him to call on them and to communicate all his information personally.

“ I have now the honor to inform you, that Mr. Kelly has made a further examination of the ground, this time on the left bank of the Ganges, up the Lal Nuddee, opposite Ghora Ghât; his men having brought in a good specimen of limestone from that locality.

“ I regret to say that Mr. Kelly has ascertained that the sample stone was a boulder merely carried down possibly from some other locality. He describes the rock *in situ* as a ‘ very hard tough stone, well suited for coarse rubble masonry, but not for dressing, as the beds are very irregular and the joints run in every direction.’ He adds, that ‘ possibly an odd stone might turn out in quarrying down a cliff,’ and that ‘ there are lots of shapeless masses of stone in the ravine hard enough for anything, but all intersected with false joints, so that they cannot be split up straight, and being in scattered blocks, the carriage would be very expensive.’ He does not think that a stone of 4 cubic feet when dressed could be found there; and his men, whom he has out on search, with the incentive of Rs. 100 reward before them, all say that at and above Rikheekes nothing capable of being dressed has been met with.

“ I may add, that although I considered Mr. Kelly's report

to be conclusive as regards the localities examined by him; and although the prospect of finding good stone within a moderate distance of Hurdwar appears to be remote; yet, the search for it shall not be abandoned."

Question 3.—"The Committee are anxious to have a copy of Professor Medlicott's Report, if it can be found."

Reply.—"Memoirs of the Geological Survey of India, Vol. III., Part 2, sent by to-day's post."

Professor Medlicott states (page 176) "that stone fitted for ornamental or monumental purposes might be found among the thick bedded hard limestone of the "Krol group." Of this group the belt of limestone and slate which crosses the Ganges between Rikheekes and the stream beyond Tupobun, would appear to be the continuation; it seems strange though, and it is most disappointing that no vein of good hard stone should be found in such a locality. But as Mr. Kelly has remarked, if there were any veins of hard stone they would probably have contributed good hard boulders of fair size to the Ganges deposits, whereas it is notorious that the limestone boulders are small, mere shingle."

P.S.—The best stone to be had in the neighbourhood of Hurdwar is the conglomerate, of which the caps of the Myapoor dam spiers are made. It is hard and durable under running water. That one was not experimented on because from the nature of it, experiment on a small specimen would be useless. Unfortunately, the quantity of this stone, which is to be had within a moderate distance from Hurdwar, is very small. The visible supply has been almost worked out.

(Signed) J. H. DYAS, LIEUT.-COLONEL,
Chief Engineer, Irrigation Works,
N. W. Provinces.

ROORKEE, }
 31st May, 1866. }

EXTENSION OF THE CANAL FROM CAWNPORE TO ALLAHABAD.

133. In the concluding paragraph of his first letter to the Government of India, Sir Arthur Cotton has strongly urged the necessity of carrying the canal as a line of navigation to Allahabad, as the point "which is essential to its effective operation;" and the Committee have accordingly given the subject their best consideration, especially as it appears to have been Sir Proby Cautley's original intention to adopt the same terminal point.

Sir Arthur Cotton's plan for extending the canal navigation to Allahabad.

134. The length of that part of the Doab is 120 miles, and its average breadth under 25 miles; it is bounded on each side by a

Area of the lower part of the Doab and its means of communi-

cation very favorable appears to render the extension not necessary at present.

navigable river, and intersected throughout by the East India railway, and the Grand Trunk road, and it appears to the Committee that no part of India is better provided in proportion to its area of 3,000 square miles with the means of transport, either for its own produce in favorable seasons, or for that of other districts for its relief in times of scarcity, and they therefore fail to perceive the necessity of an expenditure of at least 15 lakhs, in carrying a navigable canal through this narrow tract.

The irrigation of the extremity of the Doab not required so much as its extension in the upper districts.

135. With regard to the irrigation of this extremity of the Doab, the Committee have been informed that the failure of rain is less frequent there, than further northward, but without accepting this as an ascertained fact, they may remark that it will be equally advantageous and more economical, to extend irrigation in the upper districts, as the great length of the canal has unquestionably been one material cause of its heavy cost, and disproportionate financial returns.

The extension to Allahabad not recommended.

136. While, therefore, there are other objects of so much more urgent importance in connection with the canal, demanding attention, the Committee cannot do otherwise than advise that the Allahabad extension should for the present remain in abeyance.

FINANCIAL STATE OF CANAL.

Nett receipts from canal do not cover interest on capital.

137. The annual statement of remunerative works in the N. W. Provinces, exhibits the Ganges canal in an apparently hopeless state of indebtedness. The total expenditure on new work is charged with interest at the rate of 5 per cent., and the expenditure up to the end of 1863-64, having amounted to upwards of 2 millions, the charge for interest is over 10 lakhs of rupees. The total income for that year was Rs. 7,73,390, and the expenditure in maintainance and for establishments was Rs. 6,09,711, leaving only Rs. 1,63,679 to meet the charge of 10 lakhs. About Rs. 8,40,000 thus appear at the end of the year as a balance of charges against the canal. This operation which has been going on from the commencement has caused the accumulated charges up to the end of the year 1863-64, to amount to upwards of 83 lakhs of rupees.

Remunerative statement not a fair criterion of the merits of the canal.

138. If the above procedure be accepted as correct, it is evident that the canal must be pronounced a failure as a commercial speculation, until the nett receipts shall exceed the annual charge for interest. The Committee do not however consider that the annual statements of remunerative works, from which the foregoing particulars are taken, are at all a fair criterion of the merits of the canal.

Policy of Government in levying low water-rates.

139. The statement to the following effect of Colonel Colvin, which Major Crofton has quoted in his Report, well deserves attention; "that the object of Government was not so much to form a productive source of revenue from the actual price paid for the water, as to gain

a sufficient control over its expenditure and to prevent its being wasted, and that they looked to the general improvement of the country as the source from which they should derive a return adequate to the outlay." The Committee believe that until very recently the Home Government continued to hold the same views, and it is to this policy the extraordinarily low water-rate which has been charged on the Ganges canal up to the end of 1864-65 is to be attributed.

140. The Committee are not aware to what extent per acre the land revenue of the country watered by the Ganges canal has been enhanced by irrigation; but they are of opinion that whatever it may be, it should appear as an item of canal revenue, and if it cannot be separated from the ordinary land revenue, and incorporated with the proceeds from water-rates, it should at least be exhibited in the annual returns to the credit of the canal. On this point the Committee entirely agree with Colonel Dyas, who has expressed his views in the following terms in his report for 1863-64.

Increase of land revenue due to this canal should be exhibited in remunerative statement.

141. "Nothing appears clearer to me than that all proceeds resulting from the construction of a work of irrigation should be clearly shown, whether they happen to be on the debtor or on the creditor side, whether profit or loss, for if they are not shown, how is it possible for Government to know whether it is advisable to construct any new work. It matters little under what names or heads the proceeds are shown, whether as land revenue, enhancement of land revenue, diminution of land revenue (a negative proceed) or water-rate; the one thing needful is to show them all clearly and not to allow any of them to be muddled up with the land revenue proper, that is, with the land revenue assessable, had the canal no existence."

Colonel Dyas' opinion on the subject quoted.

142. As an example of the effect of a canal in the N. W. Provinces in improving the land revenue, we quote as follows from a report also by Colonel Dyas, with reference to the Meerut district, watered by the Eastern Jumna canal.

Increase of land revenue due to irrigation on Eastern Jumna canal.

"Of that district at the time of the settlement, 71,920 acres were irrigated, and the land revenue from that land in 1848 was Rs. 1,35,195; hence the rate of land revenue for land irrigated at the time of the settlement is Rs. 188 per 100 acres.

"Of the same district, 4,58,896 were (in 1848) unirrigated, and the land revenue secured amounted to Rs. 6,35,893, hence the rate of land revenue for unirrigated land is Rs. 138 per 100 acres.

"The increase therefore due to the Eastern Jumna canal is Rs. 50 per 100 acres, or eight annas per acre."

143. As regards the Ganges canal, it would appear that it has not heretofore received credit for any increase of land revenue, and it was impossible that the low water-rate that was charged up to the beginning of 1865-66, should alone suffice to return a profit on the capital expended.

No similar benefits on Ganges canal, and water-rates insufficient to yield a profit.

Probable increase due to Ganges canal assumed at 8 annas per acre of irrigated area.

144. Should however an increase of land revenue equal to that which as above has accrued to the irrigated land under the Eastern Jumna canal, be credited to the Ganges canal when the new settlement comes into operation, the annual receipts will be increased by 8 annas per acre, or about 583,000 acres, or nearly 3 lakhs of rupees. From the returns obtained by Colonel Dyas from the Collectors, it would appear that in two districts alone, the enhancement due to irrigation amounts to Rs. 97,863, and the above estimate is more likely to be below than above the mark.

Water-rate increased from 1st May, 1865.

145. Fortunately for the future prospects of the canal, the Government have lately sanctioned the introduction of increased water-rates. From 1st May, 1865, they will be equal to about double what they were before. The average yield for last year will be about Rs. 2-4 per acre. Should the area of land irrigated by flow of water or gravitation, as compared with that irrigated by machinery, be raised, as is certain to be the case when the full supply is admitted into the canal, the profit per acre will be considerably increased, and for future calculations, Rs. 2-8 is more likely than Rs. 2-4 to be the average rate.

Revenue from canal for 1865-66.

146. The irrigation returns for 1865-66, have been received by the Committee. The receipts will be as follows:—

Water-rents—Khureef,	Rs.	4,88,353
„ Rubbee,	„	7,43,806
Miscellaneous receipts from sale of produce,	„	63,226
Receipts from navigation,	„	43,662
Total, Rupees,		<u>13,39,047</u>

Charges and nett revenue.

147. The charges for the year for repairs and establishment which the Committee have obtained from the Controllor, P. W. Accounts, N. W. Provinces, amount to Rs. 5,98,531, the nett receipts will therefore be Rs. 7,40,516.

Return on capital outlay.

148. The total expenditure on new works on the canal, including rajbuhas, up to the end of 1864-65, was Rs. 2,08,14,654, the interest at 5 per cent., 10,40,732; the nett receipts only yield a return of fully $3\frac{1}{2}$ per cent.; but if the enhancement of land revenue due to the canal, which is estimated approximately at upwards of Rs. 2,90,000, be credited in the receipts, the return for the year would be 5 per cent. on the outlay.

Failure of canal though in an unfinished state, of a modified kind.

149. However, if only the canal revenue proper is taken into account, the above figures show that the financial failure of the canal, even in its present half developed state, is of a very modified kind.

Progressive improvement certain.

150. An increase of irrigation may be confidently anticipated, and as the charges for establishment and maintainance do not increase in the same proportion, the nett receipts will go on steadily increasing year by year. While for the five years, from 1860-61 to 1864-65, the quantity of water discharged by the canal remained nearly uniform,

the irrigated area increased during that period from 3,42,909 acres to 5,66,514 acres, the revenue (at the old water-rates) from Rs. 6,45,111 to Rs. 9,90,866, and the area irrigated by each foot of discharge from 73 to 141 acres.

151. It is found on the old established canals from the Jumna, that each cubic foot of discharge irrigates from 190 to 290 acres; the average may be taken at about 220; and if the Ganges canal attains to this standard, its full supply of 6,750 cubic feet per second will irrigate 14,85,000 acres. But allowing only 200 acres per cubic foot, the area would be 13,50,000 acres, which at Rs. 2-8 per acre, will yield 33,75,000 rupees; to which may be added, at the lowest computation, 2,25,000 for miscellaneous revenue receipts and for navigation tolls or in all 36,00,000, exclusive of enhancement of land revenue.

Ultimate duty of canal calculated.

152. Major Crofton estimates the total cost of the project, including all works in the original design, except the extension to Allahabad, at Rs. 3,10,00,000. If the additional works the Committee have recommended, raise the cost to Rs. 3,25,00,000, the annual charge at 5 per cent. will be 16½ lakhs of rupees.

Charge on capital to be met.

153. The maintenance eventually will, it is confidently expected, be on a far lower scale than it has been of late years, seeing that there have been unusually heavy repairs to masonry works, and extensive clearances due, not to the silt admitted from the river, but to the erosion of the bed and sides of the channel. Probably 7 lakhs per annum will suffice to cover all expenses. The nett returns would then be 29 lakhs, which would not only suffice to cover the charge of 5 per cent., but to pay off the accumulated interest of former years, and that once effected, to yield a clear profit of 8 per cent. per annum exclusive of the enhancement of land revenue.

A good return anticipated.

154. Considering therefore all the circumstances noticed above, which have hitherto tended so materially to frustrate the success of the Ganges canal in a financial point of view, the Committee are of opinion that its comparative failure up to the present time affords no ground for doubt of a fair and reasonable return from other irrigation projects, constructed with the express object of yielding a direct profit.

Delay in returns from Ganges canal should not disparage projects for irrigation works.

155. In concluding their enquiry into the financial prospects of the canal, the Committee would observe that complete economy in the use of water for irrigation cannot be looked for until the charge is made on the cubic quantity taken, and not on the area of land irrigated, as is the present practice.

Water should be sold by measurement.

156. Under the present system no inducement is afforded to the cultivator to make the most economical use of the water; on the contrary, every inducement is towards wasteful profusion.

Cultivator not encouraged at present to economize water.

157. He pays the same tax per acre, for a particular crop, whatever may be the amount of water thrown upon it; and thus, if by throwing double the quantity upon the land he could increase the

Water-tax according to area irrigated, without reference to quantity of water expended.

yield by only 2 per cent., it would be to his pecuniary interest so wastefully to apply it.

Area irrigated per cubic foot per second on Ganges canal.

158. The number of acres irrigated on the Ganges canal by each 1 foot per second of discharge has been increased during the last five years from 73 to 141 in 1864-65.

Area irrigated on Eastern Jumna canal.

159. The quantity irrigated by each foot per second of discharge on the Eastern Jumna in 1864-65 was 220 acres.

Capable of further increase.

160. But this is far below the theoretical maximum; and, as in the latter canal the rajbuhās are now doubtless fully developed, indicates some defect in the system of disposal.

Quantity of water required for a wheat crop. Mr. Login's evidence.

161. Mr. T. Login, an officer of great experience in these subjects, reports that from careful experiment he found that four waterings of $2\frac{1}{2}$ inches, or a total of 10 inches in depth of water, was amply sufficient for a wheat crop in these soils.

Opinion of cultivators.

162. A common concord of opinion amongst cultivators is that one foot of water suffices for a wheat crop.

Duty which should be performed per cubic foot of discharge.

163. Allowing 20 per cent. of the whole discharge for absorption and evaporation, this would make the total required 15 inches in depth; or one foot per second of discharge should theoretically irrigate 580 acres of crops, consuming equal amounts to wheat crops, assuming that the water were fully utilised throughout the year.

Four times the quantity required for a wheat crop expended at present.

164. The quantity of land actually irrigated by the Ganges canal in 1864-65 was 141 acres per 1 foot of discharge per second, and the depth of water consumed was 5.17 feet, or deducting 20 per cent. = 4.65, or nearly four times the quantity actually said to be required for wheat crops.

Theoretical duty per cubic foot Khureef and Rubbee combined.

165. But of the whole area irrigated, 30 per cent. consists of Khureef crops; which, on the average, as at present composed, consumes nearly the same total quantity of water as the Rubbee crops. Assuming the present proportion of Rubbee and Khureef, and the present composition of Khureef crops to remain the same, and assuming that the water on the Khureef is equally utilised, then the area irrigated of average crops, both Rubbee and Khureef, should be 414 acres per cubic foot of discharge.

Economy of water not of importance heretofore, but will be very necessary when canal is completed.

166. The Committee are aware that the subject of the disposal of water by cubic measurement has from time to time engaged the attention of the canal officers, but as owing to the imperfect development of the rajbuhās and to the demand for water for extension of irrigation being of gradual and slow growth, the necessity for economy of water has not been so urgent as it will be when the canal shall have been completed.

Committee recommend a course of experiments on water-meters.

167. The Committee would therefore recommend that the experiments now being made at Roorkee should include a comprehensive enquiry into the feasibility of bringing into use a cheap and effective water-meter, and they are of opinion that the great importance of the subject would warrant a liberal outlay.

**COMPARISON OF FINANCIAL RESULTS OF MADRAS
IRRIGATION WORKS WITH THOSE OF
THE GANGES CANAL.**

168. The financial results of the Great Irrigation Works in Southern India have been so prominently adduced as examples of what the Ganges canal, if constructed on sound principles, ought to have yielded, that the Committee think it necessary to remark briefly on the very different circumstances under which the works in the Northern and Southern Provinces appear to have been carried out, which are explained more fully in separate papers,* recorded by two of their number.

Works in Northern and Southern India carried out under different circumstances.

169. It appears that in Madras nearly all the large works undertaken by the British Government have been to an important extent for the purpose of restoring and developing irrigation systems which, in a more or less imperfect state, had existed for ages. In Tanjore especially extensive channels from the Cauvery covered the Delta, and needed only proper regulation to render them thoroughly effective. In the Godavery and Kistna Deltas also, it is stated, that numerous old channels, some of which were of considerable size, had served to distribute, though imperfectly, a supply of water from those rivers. They were incorporated with the Delta systems dependent on the anicuts, and formed serviceable feeders of the new canals, thus saving a considerable cost in excavation, and expediting the distribution of the improved supply of water.

Madras Delta works chiefly designed to improve and develop old systems of irrigation.

170. In other districts, extensive reservoirs of ancient construction, required only the powerful aid of weirs across the feeding rivers, and in some cases connecting lines of channel, to restore and develop their storage capacity to its fullest extent.

Ancient reservoirs improved by the construction of weirs.

171. Further, the rapid extension of irrigation in the South has been materially promoted by the fact of the people being accustomed to that mode of cultivation, and by their readiness to avail themselves of the large tracts of waste land fit for the cultivation of their great staple, rice, which can be raised only by artificial flooding in all the irrigated districts.

Rapid extension of irrigation in Madras.

172. The Ganges canal on the other hand is an entirely new project from which no return could be derived, till the main works had been completed, and the results of which must necessarily depend on the gradual development of an entirely new system of branches. Wheat, the great staple produce, can be raised in favorable seasons at moderate expense by well irrigation, and the proportion of available waste land is but small, added to which, although the water-rate has been fixed very low, the sale of water depends wholly on the demand

Difference of circumstances in the Ganges canal.

* Appendix B and C.

on the part of the landholders, which it is understood is not the case in Madras, while canal irrigation in these provinces is of but recent introduction; and not, as in the South, a system practised for centuries.

Difference of relative levels to the land between the Delta rivers and those of the Northern Doab.

173. The Committee consider the foregoing causes sufficient to account for a great and apparently disadvantageous contrast between the North and South; but when it is also borne in mind that owing to the essential difference between the relative levels of the Delta rivers to their field of irrigation, and those of the Northern Doab to the adjacent land, a vast additional expense must be incurred in the latter case, in bringing the water to the surface, whether by taking off a canal from above or below the rapid slope of the bed following the debouchment of the river from the hills; they cannot but feel that no just comparison can be made between the results of works so very different in character as those referred to.

ACKNOWLEDGEMENTS.

174. With reference to para. 10 of the order of Government, No. 20,410, the Committee desire to acknowledge the assistance and information they have received from Colonel Dyas and the Executive Engineers under his orders.

They were also favored with the valuable evidence of Mr. T. Login, late Superintendent of the Northern Division of the canal, as to its past history.

They regret that owing to the urgent pressure of his duties in Cuttack, Colonel Rundall was unable to join them in their inspection of the Ganges, and although that officer offered to reply to any written questions referred to him, they did not consider it expedient to delay their proceedings for that purpose, when personal examination of the localities seemed essential for arriving at a correct opinion; so far however as can be judged from Colonel Rundall's unofficial communications, it would appear that his views as to the best site for the weir and line of canal near the Solani, do not differ materially from those adopted by the Committee.

175. The Committee would further record their best acknowledgements of Major Crofton's unwearied efforts to promote the objects of their enquiry, both by efficient arrangements for their movements and by full explanations of his own plans.

EDWARD LAWFORD, COL.-COMMANDANT, R.E.

J. C. ANDERSON, LIEUT.-COLONEL, R.E.

J. G. FIFE, LIEUT.-COLONEL, R.E.

HUGH LEONARD, C.E.

MUSSOORIE, }
18th June, 1866. }

DISSENT.

1. I dissent from the above report mainly as to conclusions No. III. and No. IV., the first negating the proposed canal [from the Jumna near Delhi (bringing 3,300 feet per second to complement the present 4,400 now brought down by the main canal), as a substitute for the remodelling above the junction; the second recommending that the remodelling, according to Major Crofton's plans (with certain modifications), be at once proceeded with.

2. In reference to the latter's conclusion, I dissent from paras. No. 140 and 142 of the report, which state that the main difficulty in the remodelling, as proposed by Major Crofton, lies in the depth of the cisterns below the new falls, and which further state that if these cisterns be modified, the work up to water line may be executed during two closures of the canal, each of $3\frac{1}{2}$ months duration.

3. I dissent from this latter conclusion, because Major Crofton has, after careful investigation, expressed his opinion, in para. 102 of his report, that to execute the work as designed by him, the necessity for shutting off the canal supply for at least one irrigating season is inevitable, and that an entire year would not be too large an allowance; because Colonel Dyas, the Superintendent, Irrigation Works, N. W. Provinces, has concurred generally in that opinion; because in my judgment the period assigned is rather understated to carry out the works as designed; and because I do not regard the deep cisterns as the most troublesome part of new falls, nor nearly so likely to cause uncertainty and delay as the well foundations; and I decidedly do not think that the proposed modification of the cisterns would render it probable that the work up to water line could be executed (except at entire disregard of cost) during two periods of $3\frac{1}{2}$ months stoppage of the canal.

4. Further, I am not satisfied with the estimate of probable loss from such a closure for $3\frac{1}{2}$ months, Colonel Dyas having been asked for a statement of such loss and having not yet given it because he had not sufficient information.

5. In respect to conclusion No. IV., I dissent because I hold that it is only as a last resort that the serious evil of stopping the canal supply for a whole year, if not longer, should be incurred, and because the proposed canal from the Jumna offers a mode (if the 3,300 feet per second discharge of the Jumna and Hindun rivers can be depended upon, and for which conclusion there appears to me to be strong *prima facie* ground) of making up with the 4,400 feet per second now brought down the main canal, an amount of water supply in excess of that provided under the remodelling scheme, at a less, or certainly not greater cost, and without incurring the serious evil of stopping the canal supply.

6. For the further elucidation of this subject, I refer to the Memo. in that project, printed in Appendix A., and I recommend that during the next season, a complete survey should be made of that project, and that, in addition to daily record of water level, the discharges of the rivers Jumna and Hindun should be taken on the 15th of each month, from October to May inclusive, and that if the result should show that a quantity approximating 3,300 feet per second can generally be relied upon during those months, then the canal from the Jumna should be made in supersession of the remodelling above the junction, if it be determined not to execute both, or in priority to the remodelling if it be determined that both should be carried out.

7. I further recommend that, meanwhile, stone and other material should be collected at existing falls, sufficient for their complete repair should failure occur, but that no further steps should be taken towards the remodelling above Nanoon junction, until the question of general minimum discharge of the Jumna and Hindun be settled.

8. I dissent generally from paras. No. 70 to 89 of the report, treating of the Jumna project.

9. In reference to para. 71 of the report, in which it is stated that the water gauge kept at the railway bridge at Delhi, was not a safe guide, because it was affected by the damming up of the bridge spans for girder erection purposes. I would point out that this damming gradually increased in extent from the beginning to the end of the dry season; and, consequently, so far as it affected the water level, would have the effect of making it appear relatively higher in April than in December.

10. I dissent from para. 73, which decides to adopt the same section for weir at Toghluhabad on the Jumna as at Sookertal on the Ganges. At Toghluhabad there is a practicably unlimited supply of stone from the old fort, much of it dressed, and any further quantity of rough stone can be quarried within 3 miles of the work.

11. At Sookertal there is no stone within 50 miles, and probably no sufficient supply of fit stone within 66 miles, and this last has not yet been explored.

12. These conditions are so essentially dissimilar as, in my judgment, to demand different treatment.

13. For the above reasons I dissent from the estimate of weir across Jumna given in para. 81.

14. In reference to para. No. 101, I do not concur in ascribing the deep holes below the falls, chiefly to the increased velocity with which the water escaped from the floorings.

15. I think that the most serious part of that scouring is due to the wings which curve inward, thus reducing the width of the channel, and throwing a current at right angles to the direction of the stream, by which a rotary motion is produced, and deep scouring naturally follows.

16. Had the scouring been chiefly due to the velocity of the water over the crib work, the greatest depth of scouring would naturally have been looked for immediately close to the crib work, where the light soil joins the protective work; but the deepest scour is not found there, but at a considerable distance lower down, and just where the conflicting currents are converted into a rotary motion.

17. At Nirgajnee falls (next below the Mahmudpoor falls) which is without these inward-curved wings, but little scour has taken place.

18. I would recommend that these inward-curving wings be altered at once, the work could be done without interrupting the canal.

19. On the subject of the supply of stone referred to in paras No. 130 and 132, it should be noted that Colonel Dyas' experiments were made on the Sewalik sandstone lately brought in, and are not necessarily to be regarded as representing the crushing weight of the sandstone seen in the old buildings at Hurdwar.

20. A more important point on the subject of stone is that the report does not, in my opinion, lay nearly sufficient emphasis on the importance of examining the apparently unexplored field in the main Himalayas in the neighbourhood of Luchmun Joola and Tupobun, where, at a distance of about 17 miles from Hurdwar, the hills for miles in extent appear to be formed of a hard ferruginous clay slate, and rather farther up the valley of the Ganges, of evenly stratified whin-stone.

21. Should a good building stone be discovered there, it would reduce the estimate for the weir at Sookertal by upwards of 4 lakhs, and would reduce the cost of ashlar stonework executed on the upper portion of the canal by from 30 to 50 per cent.

GEORGE SIBLEY.

APPENDIX A.

Memo. on a project for making a canal from the Jumna at Togh-lukabad, about 10 miles below Delhi, to the main canal near Birowlee bridge (or to the Simra falls), about 20 miles above Nagoon junction, the head of the Cawnpore and Etawah branches.

1. In considering the relative merits of the various schemes for obtaining the desired result, of bringing down the full amount of water which the canal was originally designed to carry, there should be kept constantly in view the vital importance of not closing the canal and stopping irrigation, except as a last resort.

2. In para. 97 of Major Crofton's Report he writes, "the absolute necessity of maintaining uninterruptedly the present volume of water to supply existing irrigation, unless there be very cogent reasons to the contrary, is assumed by all."

3. In para. 102, he states his conclusion that for executing the work proposed by him in remodelling, "the necessity of shutting off the canal supply for at least one irrigating season, or half a year, appears inevitable, and to do the work satisfactorily and give time for the larger masses of masonry to harden sufficiently, an entire year would, in my opinion, not be too large an allowance."

4. This opinion is concurred in generally by Colonel Dyas, Superintendent Irrigation Works, N. W. Provinces.

5. The Committee of Engineer Officers summarised the advantages of a duplicate channel to complement the supply, as presenting—

1st.—Facility of construction, and of forming reliable estimate of time and cost of construction.

2nd.—The very great convenience that may be anticipated from the possession of a duplicate line of main channel, which would admit of a considerable amount being sent down to the lower parts of the canal, while either of the main lines was closed for repairs.

6. Sir P. Cautley (in page 75 of the Discussion) writes, "the remedy however appears to be rather in the division of the great body of water and thereby in diminishing the effect of its action, than in the continuance of the existing channel as a single line:" again (in page 76) he writes, "I am much in favor of *reducing the present volume*

“ *of water in the main canal, with so many falls and 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 evil of accident on one line will (as far as supplies for irrigation to the South are concerned) be neutralised by the existence of an alternative line.*”

7. Sir P. Cautley also, in his Memo., printed in Appendix A. to Major Crofton's Report, insists on the value of having an alternative line for the security of the irrigation of the Southern districts; in this view, and also to avoid the serious evil of stopping the irrigation for an indefinite period Sir P. Cautley proposed a duplicate channel, leaving the main channel below Roorkee.

8. The Government of India in reviewing Major Crofton's Report rejected this project for an alternative channel—1stly, because it appeared from Major Crofton's figures that it would be more costly than the remodelling by some 30 lakhs; and secondly, and chiefly, because it appeared that the really serious objection to the remodelling, the necessity for closing the canal for a while, was found to be equally applicable to that scheme.

9. The Government of India at the sametime remarked that, had there been a prospect of the scheme being practicable without the necessity for closing the canal, it might have been thought desirable to incur additional outlay to avoid such serious interference with the convenience of the agricultural community, though it might have been doubtful whether even on that ground so large a charge as 30 or 40 lakhs should be incurred.

10. Major Crofton's comparison of the cost of the remodelling with Sir P. Cautley's alternative line, was based on the supposition that the present channel could carry with safety only 1,870 feet per second below Roorkee, leaving the alternative channel to carry 5,000 feet per second, or nearly three-fourths of the whole quantity.

11. Now, it appears that, since the last closure in August, 1864, (a period of 21 months) the canal has carried regularly 4,400 feet, being $2\frac{1}{2}$ times the estimated safe quantity; that the action in the bed, falls and bridges, has been carefully watched, and that no injurious action worth noting has been ascertained to have occurred.

12. This fact, as to the comparatively favorable condition of the works, if well established, would lead to the conclusion that only 2,500 feet instead of 5,000 feet need have been provided for in the new channel, and would so far modify the comparison of cost between the alternative channel and the remodelling scheme; as, however, the alternative channel was rejected, not so much on the ground of extra cost alone, as on the ground that the serious evil of closing the canal appertained to that scheme also, it does not appear to be necessary to go into the question of how far the comparison between the two projects would be modified.

13. Without having the canal laid dry, it is of course impossible to state with absolute certainty whether any seriously injurious action has taken place, but the concord of evidence from surface observation leads to a contrary presumption.

14. The Committee made a formal request to Colonel Dyas, the Superintendent of Irrigation Works, N. W. Provinces, to have the waters shut off for a few days, so as to enable them to satisfy themselves, by actual inspection, as to the condition of some of the more important and previously threatened works, but this request was met by objections so numerous and so strongly urged as almost to amount to a protest, and under these circumstances the Committee decided not to press their request.

15. Colonel Dyas reports as to the condition of the works since the date of Major Crofton's Report, as follows:—

“ As to the bed, erosion is no doubt going on in many places, inasmuch as during the cold weather, when the water coming in from the Ganges river through the Myapoor regulators (the head of the canal) is almost quite clear, the water in the canal gradually becomes very muddy ; but a comparison of the cross sections of the canal bed, which I have lately had taken at every mile along the canal, with similar sections taken by Major Crofton in 1864, shows that no dangerous action is going on at present.

“ As to falls in the Northern division (from Myapoor to Jaolee) the extent of damage done, as far as can be ascertained by careful sounding and probing, consists of a slight displacement of crib work battens. In the Meerut division two falls have been slightly injured, but not sufficiently as to warrant a closure of the canal for the purpose of repairing them. The Chitoura fall, 55 miles 4,976 feet, has had part of the ogee in No. 3 bay ripped out, and that bay is kept close in consequence to prevent further damage ; and the Sulawur fall (67 miles 2,350 feet) has had two of the hammer-dressed Delhi stones in flooring of No. 3 bay turned over : this occurred in September, 1864, and the stones have not moved since. The bridges are all secure.”

16. The result of the last 21 months' working appears therefore nearly conclusively to show that for a lengthened period this quantity of 4,400 may be safely sent down the present channel, so that if a quantity equal to that which is required for the irrigation below Birowlee bridge, on the Simra falls, can be brought in from any independent source, the whole irrigation below that point may be permanently secured ; and if by repairs, such as may be effected during the ordinary periods of closure (the cost of which Major Crofton estimates at Rs. 1,06,424), the old channel may be made securely to carry permanently the present 4,400 feet per second, the result would be that a total quantity of 7,700 feet per second would be available for irrigation (as compared with the 6,742 feet of the remodelling scheme), and this result would be obtained without stopping the irrigation.

17. It appears from an examination of the country and of the levels, that such a complementary channel could be made at moderate cost by leading the water from the Jumna, opposite Toghluabad, about 10 miles below Delhi, crossing the Hindun, and taking its waters also, and joining the main line at or near Birowlee bridge, near the 158th mile from Hurdwar.

18. The minimum discharge of the Jumna for this year, as appears from sections taken by the Resident Engineer, of the Jumna bridge, on the 9th April, 1866,

Being	2,820
And that of the Hindun, taken by an Assistant Engineer of the Railway at Gazeabad, ..	480
	3,300
	Gives a total,

feet per second, which is very nearly the full amount required below the Birowlee bridge, on Simra falls, according to Major Crofton's scheme.

19. This discharge is corroborated by the discharge taken at Agra by Mr. Dodd, Executive Engineer, on the 5th April, 1866, which showed 3,544 feet per second, and which he reports to have been the lowest for the season.*

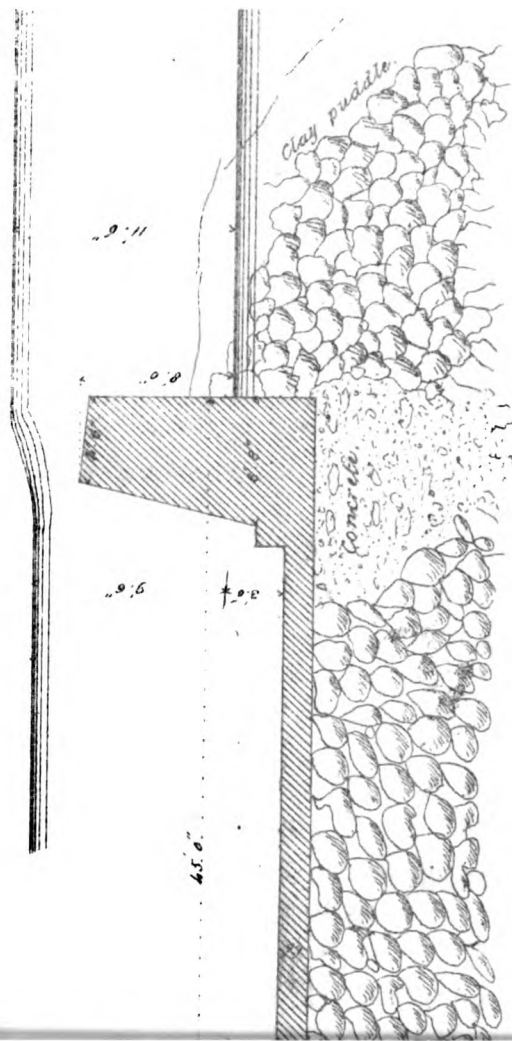
20. The Resident Engineer of the Delhi Railway bridge, who took the discharge on the 9th April, and who is on the river daily, reports however, that he is perfectly confident that the river was at its minimum for the season on the 9th April, that there was only 9 inches difference between water level on that date and on the 19th December, a difference that was fully accounted for by the channels having been bunded for the purpose of girder erection.

21. There appears to be at least sufficient *prima facie* evidence of the general correctness of the minimum discharge taken, or 2,820 feet per second, to demand further investigation.

22. Toghluabad is a very favorable position for the building of a weir across the Jumna—firstly, because the river bank, opposite the village of Alee, is of a very firm character (kunker and clay); and secondly, because there is a practically unlimited supply of stone admirably suited for such purposes, a very large amount of rough stone and a very considerable quantity of dressed stone (Delhi quartzite), being available from the ruins of the old fort of Toghluabad, which is also built on rock.

23. A channel 130 feet wide at base, 10 feet deep, with slopes 2 to 1, and fall of $4\frac{1}{2}$ inches per mile, giving a velocity of 2.20 feet per second, would discharge 3,300 feet per second, and would fall into the main canal at about the 158th mile from Hurdwar, or about 22 miles

* A doubt has since been thrown as to whether this was lowest minimum discharge, by its having been stated that the discharge of the Jumna on the 19th December, 1865, was only 829 feet per second.



N. B. Body wall to be built gradually to full height.

above Nagoon junction, the head of the Cawnpore and Etawah branches.*

24. An approximate estimate of such a channel and weir shows that they could be executed for about 39 lakhs (£390,000) including superintendence.

The amount is composed as follows:—

Earthwork,	Rs.	20,59,788
Bridges, &c. (19),		3,80,000
Weir and regulator at Jumna,		6,64,000
Weir and regulator at Hindun,		2,10,000
		<u>33,13,788</u>
Add contingencies, at 8 per cent.,		2,65,103
		<u>35,78,891</u>
Add establishment, at 7 per cent.,		2,50,522
		<u>38,29,413</u>
Land, 57 miles at 64 acres per mile, at Rs.		
24 per acre,		87,552
		<u>39,16,965</u>
Total, Rupees,		39,16,965

25. In the above estimate earthwork cutting, depth average 10 feet, has been taken at Rs. 3 per 1,000; and average depth 20 feet, Rs. 4 per 1,000. In the estimate for weir at Jumna, the rough rubble stone is taken at Rs. 10 in place, and the dressed masonry at Rs. 30 per 100 feet; probably the whole of the material required being obtainable from the old fort of Toghluhabad; or if further rubble stone be required, it can be quarried within 2 miles of the weir.

26. It is considered that with the mass of rubble stone available, and with a good puddle clay on the spot, wells would not be needed under the weir wall; if a double row of wells be added, they would increase the estimate by about Rs. 2,00,000.

27. In the estimate for Hindun river weir, the actual rates of work in the Hindun railway bridge have been adopted.

28. The percentage for contingencies and for establishment have been taken the same as in Major Crofton's alternative line.

29. To the total,	Rs.	39,16,965
As above, there is to be added—		
Remodelling between Birowlee bridge and Nagoon,		3,58,458
Repairs above Birowlee,		1,06,424
Re-adjusting rajbuha heads above junction,		1,00,000
		<u>44,81,847</u>
Remodelling Cawnpore branch, as per Major Crofton's estimate,		4,26,842
Giving as expenditure, Grand Total, Rupees,		<u>49,08,689</u>

* It might prove advisable to bring in the new channel below the Sirma falls, 5 miles lower down, or about the 168rd mile.

30. Major Crofton's estimate for remodelling the old canal—including the Cawnpore branch is,	39,19,850
Of which is debited for navigation above Birowlee,..	9,05,000

Leaving debitable to irrigation, Rupees, .. 30,14,850

Now, though the above amount (9,05,000) may as a part of a whole be fairly debitable to navigation, it is doubtful whether the work due to irrigation alone could be executed for the balance.

31. Assuming however the above figures, to that balance, would have to be added the difference of cost between that of a permanent dam at Hurdwar, without which the full supply could not be relied on, and the capitalisation of cost of maintaining present bunds which suffice for present supply, this difference will probably not be less than Rs. 5,00,000.

32. Again is to be added the amount of loss and compensation due to the stoppage of the canal. In Major Crofton's estimate, this is put down at Rs. 13,48,213, but in this the canal revenue is taken at only Rs. 7,73,390, since the date of that estimate the rates have been raised, and it is expected that the canal revenue will, before the work can be undertaken have reached 15 lakhs.

	RS.	RS.
To the above,		13,48,213
Will therefore have to be added, ..	15,00,000	
	7,73,390	7,26,610
		<hr/>
Giving a revised total,		20,74,823

33. The cost of the remodelling scheme then, exclusive of navigation above Birowlee, becomes—

	RS.
Works, as per Major Crofton's estimates,	30,14,850
Permanent head works (difference in cost), ..	5,00,000
	<hr/>
	35,14,850
Losses and compensation,	20,74,823
	<hr/>
Grand Total, ..	55,89,673
The cost of the duplicate channel scheme from the Jumna and remodelling below junction being,	48,08,689
	<hr/>
Shows a difference of, ..	6,80,984
	<hr/>

34. The rates for the duplicate channel, executed in the dry, have been taken at the same as in the remodelling; but it may be safely predicted that in work executed under pressure for time, with a "working bee," as proposed, the rates would rule far higher in the remodelling than in the duplicate channel.

35. As previously noted, the Government of India remarked, that it would be desirable to incur additional outlay to avoid such a serious interference with the convenience of the agricultural community, as would be caused by the closure of the canal; it appears however from the above figures that the duplicate line would cost absolutely less than the scheme, which involves the stoppage of the canal.

36. The disadvantages of the duplicate channel may be stated to be as follows:—

1st. That it does not improve the navigation above the junction near Birowlee to the extent contemplated in the remodeling scheme; leaving, as it does, a velocity of 4 feet per second where only 3 feet would be given by that scheme. The minimum headway is left nearly the same in both schemes by the water level being kept 3 feet 6 inches lower in the one than in the other. It is to be remembered, moreover, that the cost of such improvement is also omitted from the calculations; the improvement of the navigation below Nagoon (the really defective portion) is equally provided for in both events.

2ndly.—The asserted extra cost of maintaining and working the extra lengths. This is doubtful, the certain amount of extra establishment will probably be more than counterbalanced by the smaller bodies of water to be dealt with, and by the fact that 3,300 feet is carried only 57 miles in lieu of 158 miles.

3rdly.—The loss of head in the rajbhas owing to the full depth originally intended not being maintained in the canal. Should it be deemed advisable in any particular case, the additional head could be obtained by taking the rajbha from the fall above the present outlet—a sum of Rs. 1,00,000 has been provided for that purpose in the estimate. It is to be remembered that in any event many of the rajbhas will have to be remodelled, owing to them being below the surface.

4thly.—The extra loss by absorption and evaporation. As regards the first, the 3,300 will have to travel only 57 miles before being utilised in lieu of 158 miles, and the latter is scarcely worth taking into consideration, as assuming an evaporation equal to 60 inches per annum, the total loss on the channel, 57 miles long, would be equal to a discharge of only 8 feet per second.

5thly.—The injury to navigation in the Jumna by abstraction of the water for the new canal. The whole of the water is at present abstracted from the Jumna at the canal heads, and yet there is nearly 3,000 feet flowing at Delhi, 140 miles lower down. Agra is 140 miles below the new proposed

weir ; and practically there is in the cold weather no navigation above Muttra, but little above Agra, and but imperfect above the junction of the Chumbul river.

37. Among the advantages of the duplicate channel (from the Jumna scheme) are—

1st.—The maintaining irrigation permanently over, at least, the lower half of the main canal, and most probably over the whole, without any break from closing.

2nd.—Facility of construction, and of forming reliable estimate of time and cost of construction in the dry.

3rd.—The great convenience of a duplicate line of main canal.

4th.—The provision without extra cost of an additional 57 miles of first class navigation, without a lock in the whole length.

38. The balance of advantages appears to be so clearly in favor of the duplicate channel that, if the quantity of 3,300 feet per second can be generally relied on from the Jumna and Hindun—I have no hesitation in recommending the duplicate channel from the Jumna near Toghluhabad in preference to, and in supersession of the remodelling of the main canal above the point of junction.

39. As a matter of course no works should be commenced until that point, as to the discharge, is established ; and I would recommend that, during the ensuing season, a complete survey should be made of this project ; and that, in addition to the daily record of water level, the discharges of the rivers should be taken on the 15th of each month, from October to May inclusive.

40. I would also recommend that stone and other materials be collected at the existing falls, sufficient for their complete repair should failure occur ; but that no further steps be taken towards the remodelling above Nanoon junction, until the question of general minimum discharge of Jumna and Hindun be settled.

41. Having regard further to the facts that the above total of 6,742 feet per second is calculated, at a standard 40 per cent. in excess of present duty, to irrigate only $1\frac{1}{4}$ million acres (or if 7,700 feet per second, about $1\frac{1}{2}$ million acres), and though this higher standard of duty will doubtless be much further raised when the system of measurement by volume shall be generally introduced ; yet, seeing that the culturable area of the Doab above Cawnpore is upwards of nine million acres, of which only about 2,25,000, are irrigated by the Eastern Jumna canal, it would appear worthy of consideration whether, when the duplicate channel shall have been completed, and the irrigation of the lowest half of the canal secured, the remodelling of the main channel above the junction might not then be profitably carried out, generally as proposed by Major Crofton, but with modifications (except as to suggested shallower foundations for cisterns of new falls), as recommended by the Committee, when remarking on that project, and with such further modifications if possible (whether by use of

iron-piling or otherwise) as may avoid the necessity for any lengthened closure of the canal.

ESTIMATE of the cost a canal from the Jumna near Toghluhabad, 10 miles below Delhi, and the main line near Birowlee bridge, on Simra falls, a length of 57 miles, to carry 3,300 feet per second.

Quantity.	Description of work.	Rate.	RS.	A.	P.
	EARTHWORK IN EXCAVATION.		RS.		
c. ft.					
135,533,333	1st section, 19 miles, average depth, 9-13, ..	3	4,06,600	0	0
261,233,000	2nd ,, 14 ,, ,, 19-80, ..	4	10,44,932	0	0
202,752,000	3rd ,, 24 ,, ,, 10-59, ..	3	6,08,256	0	0
599,518,333	57 ,, Total of earthwork, ..		20,59,788	0	0
	JUMNA WEIR AND REGULATOR.				
e. ft.					
148,896	Dressed masonry,	30	1,48,896	0	0
3,474,240	Rubble stone at place,	10	3,47,424	0	0
per ft.	Regulator and lock,		67,680	0	0
2,000	Training walls,	50	1,00,000	0	0
			6,64,000	0	0
	Hindun weir and regulator,		2,10,000	0	0
	Bridge &c. (19),	20,000	3,80,000	0	0
	Earthwork, as above,		20,59,788	0	0
			33,13,788	0	0
	Contingences, at 8 per cent.,		2,65,103	0	0
			35,78,891	0	0
	Establishment, at 7 per cent.,		2,50,522	0	0
			38,29,413	0	0
miles.					
57	Land, 64 acres per mile,	29	87,552	0	0
	Grand Total,		39,16,965	0	0

GEORGE SIBLEY.

APPENDIX B.

Notes on the Comparative Financial Results of Irrigation Works in the Madras Presidency and the N. W. Provinces.

The financial results of irrigation works in Madras over estimated.

1. I have long been of opinion that the financial results of great irrigation works in the South of India have been over estimated, and that fallacious ideas of what may be effected elsewhere have been formed upon erroneous data, but it has not hitherto been any part of my duty to investigate the subject.

Other causes of increased revenue.

2. That the general prosperity and revenue of the districts in which such works have been carried out have been enhanced to a degree unknown in less favored provinces is an unquestionable fact, but as all of them are on the seaboard, it is certain that the great increase of foreign trade, and of the salt revenue, which has taken place in the last 20 years, must affect this result, and credit cannot I think be taken for the entire increase as due to the works of irrigation.

The works not entirely new.

3. Moreover (as the Government of India have recently suggested) the returns in many cases are the effect, not merely of British science and expenditure, but of an extensive system of hydraulic works which had been in operation for ages before the country came under our rule, but which had suffered deterioration, partly from natural causes, and partly from neglect, and have only recently been restored to efficiency.

Description of the works in Tanjore, by Major H. C. Cotton.

4. It is well known that the works in Tanjore are the prototype of all other improvements in the coast districts; there irrigation had been carried on from time immemorial under the river Cauvery, the channels from which covered the province, and made it the "Garden of Southern India." In 1842, Major H. C. Cotton wrote as follows: "The main branches of the Cauvery with the branch which retains the parent name, the minor channels separating from these, and the innumerable ramifications threading the surface of the Delta, are so disposed that one can scarcely believe it was a gradual work, each portion the accidental result of what had been done before, but would rather suppose it the work of consummate skill and science, planning the whole system at once and establishing it. Changes have taken place during the last 40 or 50 years, disordering in some measure

the irrigation of certain tracts, and remedies have of late years been applied, but these have been almost entirely confined to restoring these tracts to the condition they had been in at some former period. The deterioration which had occurred was due to the tendency of one of the arms of the river to absorb a continually increasing proportion of the whole of the supply, and thus to injure the irrigation dependent on the other arm. The remedy applied was the construction of weirs or anicuts across the river, and various other works, for the regulation of the supply to different channels." These works were in the highest degree successful, and the revenue which had been falling off for a number of years, not only regained its former maximum but rose far above it, and produced returns exceeding 100 per cent. on the amounts actually laid out in the works above described. It is, however, clear that such profits were due not to these works alone, but to the improvement they caused in the pre-existing canals by which their benefits were conveyed to every part of the Delta, and which had cost the British Government nothing.

Their profits not due to the anicuts alone.

5. So also the construction of weirs across the Vellaur, Palaur, Pennair, Ponnyaur, Poiney, and other secondary rivers on the Eastern coast, was expressly designed for the better supply of large reservoirs of ancient formation; which at the best had received but a precarious supply and had yielded an uncertain revenue, and which had gradually become inefficient from deposits of silt and general decay; but it cannot be fairly said that the returns in the shape of increased revenue are owing to the weirs alone, independently of the vast embankments by which the increased supply of water was stored, and which likewise were heir-looms from former rulers, by whom their advantages were fully appreciated.

Ancient tanks and channels in other districts only improved by the British Government.

6. To institute a comparison between the remunerative returns from such works as those of Southern India, and the financial results of an extensive and costly project like the Ganges canal, involving an entirely new system of hydraulic works over a tract of country hitherto destitute of all such artificial aids to cultivation, and in which the Engineers themselves were almost as much concerned in teaching the people the value of canal irrigation, as in constructing the works, is obviously fallacious, and calculated to lead to unfounded expectations and disappointment.

Comparison of the results of such works with those of the Ganges canal fallacious.

7. The greater part of the Southern Presidency depends mainly for prosperity on its ancient system of irrigation by channels and reservoirs, without which it would be almost a desert, while the N. W. Provinces are favored with a fine climate and general fertility of soil, capable in ordinary seasons, of raising a great variety of produce without artificial irrigation, the introduction of which by the British Government was avowedly intended, not as a commercial investment, but as a means of mitigating the effects of those disastrous seasons with which Northern India is sometimes visited; and it is on

The Madras Presidency dependent on its ancient irrigation works, but the N. W. Provinces not so, and the canal constructed as a preventive of occasional famine.

such occasions that the profits derived from the canal are highest, because the demand for water is greatest.

Difference of revenue systems.

8. The great difference between the Madras revenue system, under which irrigated land bears a permanent increase of assessment, and the voluntary and annual purchase of water by the Zemindars of the N. W. Provinces, is another material cause of the discrepancy upon which so much stress has been laid. The Madras Ryot pays the same amount to Government, so long as his fields are irrigated whatever the season may be, but the Zemindar of Cawnpore or Meerut looks to the clouds, and purchases canal water or not, as he may judge the prospect of rain to be favorable or otherwise.

E. LAWFORD.

APPENDIX C.

1. I am quite willing to accept Sir A. Cotton's estimate of the benefits derived from the Godavery and Kistna works. But I am of opinion that these works were carried out under exceptionally favorable circumstances; and that there are few, if any, non-Delta formations in India where the same results could be attained at the same proportional expense. Not only would Government be disappointed were they to take the returns from the Madras Deltas, as the standard which properly managed irrigation works ought generally to yield, but private companies might be led, through the same mistake, to embark in schemes which a real knowledge of the Delta works would have shown them, could not be of an equally profitable character. In the belief that a description of the peculiar advantages under which the Godavery and Kistna works were executed will not only be useful in clearing away much mis-apprehension that prevails regarding them, but will help the Government to understand better than they seem to do at present, the cause of their yielding a much higher rate of profit than the irrigation works in the North of India, I proceed to impart such information as I possess on the subject.

The high profits derived from Godavery and Kistna works attributable to the exceptionally favorable circumstances under which they were executed.

2. In the Godavery and Kistna Deltas irrigation from old channels was carried on to a considerable extent before the new works were commenced. In the reports on the Godavery, frequent allusion is made to the old channels. They are described as being very imperfect, as they opened from the river bank on a high level, which rendered them liable either to get an insufficient supply when the river was low, or an excessive one when it was high. The actual value of the channels however was not only considerable, but they afforded the means of at once distributing the water from the new main channels, and they possessed an agricultural class ready to use it as soon as it was offered them. The new works were thus enabled to return a profit much earlier than they could have done, had an entirely new system of distribution channels formed a part of the project.

Old channels for irrigation in Godavery and Kistna.

Vide Professional Papers, Madras Engineers, Vol. III., p. 115. Captain C. A. Orr's Report, No. 184; and page 159: Lieut.-Colonel A. T. Cotton's Report, No. 13.

3. That the old channels in question must have been valuable adjuncts to the new works, is shown very clearly in following extract from Captain Orr's Report. "By what has been shown as the benefit derivable from the anicut by means of the channels immediately affected by it, it will be seen, that with an expenditure of 9 lakhs, an annual increase (calculated on the lowest data) of Rs. 1,09,451 would be obtained, a result of itself sufficient to justify the construction of the anicut.

Valuable accessories to new works.

Professional Papers, Madras Engineers, Vol. III., p. 118.

Old tanks and
channels in Kistna
Delta. Former supply
defective.

4. In the Kistna Delta there were not only irrigation channels of considerable size, but a large number of tanks, both of which have been of invaluable service to the new works. Of the channels I may particularize the Pullairoo in the northern section of the Delta. Though now of moderate size, about 50 feet near the head, it is evidently an ancient arm of the river, running on a ridge like the Kistna itself, and admirably adapted for distributing the water for irrigation. It sufficed by means of numerous small branches to irrigate a large proportion of the Delta; that is when it had water. Before the construction of the anicut at Bezwada, it was liable like the channels in the Godavery, to receive either an insufficient or excessive supply, according as the freshes might be below or above the average, and like them and the channels in Tanjore, it only wanted a regular supply to secure the revenue due to the whole of the land under it. This want the anicut combined with a new head 15 miles in length, supplied, and the desired result was at once attained. The importance of this channel and its value to the new system may be understood from the fact, that when 65,000 rupees had been expended in the course of about eight years subsequently to the admission of water from the anicut, solely for clearance and repairs of the channel and its branches, 6,500 rupees only had been expended during the same period in new works and improvements. The cost of repairs to the Delta channels is under 8 annas per acre of irrigated area, and the water-rent was until lately 3 rupees per acre, or six times as much. The large expenditure on repairs therefore represents a large irrigated area.

Profit derived by
throwing in an im-
proved supply by
means of new heads.

5. Another channel existed in the southern section of the Delta and conveyed water to a number of important tanks to supplement the supply from the local rain-fed streams. A cut of 12 miles in length connected it with the anicut, and changed its supply from a variable and uncertain quantity to a certain and uniform quantity. There were 17 tanks under this channel, and the average revenue derived from them, from 1851 to 1855, that is for four years prior to the introduction of a supply from the anicut, amounted to Rs. 52,929, the minimum being Rs. 31,458, and the maximum Rs. 70,092. The revenue derived from the same tanks in 1863, the last year of which I possess the accounts, was Rs. 1,39,323 showing an increase over the former average of Rs. 86,394. The fluctuation of the revenue before the admission of water from the anicut was very remarkable; thus in the course of four years only, four of the tanks yielded respectively a minimum revenue of Rs. 0, Rs. 10, Rs. 323, and Rs. 123, and a maximum of Rs. 3,321, Rs. 2,908, Rs. 3,663, and Rs. 6,327.

Precarious cultiva-
tion done way with;
revenue secured and
increased.

6. The supply of the tanks was formerly very precarious, and the above examples testify to what extent both Government and the Ryots were liable to suffer. The immediate effect of the more certain supply from the anicut was to give confidence to the Ryots, to secure

the revenue at the highest figure to which it could have risen had the tanks received a good supply from rain, and by doing away with all risk of loss to the cultivators, to induce an extension of the cultivation, and a further increase of revenue. But without the aid of the tanks and the channels leading to them, which were, as I may say, superadded gratis to the anicut works, the same increase of revenue could not have been attained, excepting by a large additional expenditure on new channels or tanks, and a delay of several years.

7. Besides the above, there are another series of tanks in the Kistna Delta which were fed by a number of small channels from the river. A short branch from the new main channel into a cutting which had been formed to make an embankment along the river, fed these tanks with a regular, instead of their former precarious supply, and a large increase of revenue was the result.

Another series of tanks in Kistna Delta.

8. It will thus be seen that the Godavery, and still more the Kistna Delta works, started in possession of some advantages over an entirely new system of works like the Ganges canal, where not a single village channel existed along the length and breadth of the country to be irrigated, and where the cultivators were unused to any other mode of irrigation but that by means of wells. The Godavery and Kistna works have other advantages in regard to the alignment of new channels, which alone would render a comparison between them and the canals in the N. W. Provinces, altogether unfair.

No old works of irrigation in the country traversed by Ganges canal.

9. The anicuts which have been constructed across the Godavery and Kistna are about 14 and 19 feet, respectively, above the bed, and the ground along the banks may be from 13 to 17 feet above the crest of the anicuts. The heads of the main channels are between 5 and 6 feet lower than the crest, consequently the depth of cutting will be from 18 to 22 or 23 feet.

Depth of cutting at head of main channels in Godavery and Kistna Deltas.

10. If this depth of cutting had to be maintained for any considerable distance, the expense of conveying the large body of water required for the irrigation of the Delta would be very great. But the fact of the country to be irrigated being liable to periodical inundation by the river from a remote period, implies that the deposits during a series of years have raised the land along the banks to a higher level than that at a distance from them, so that the deep cutting at the head of the main channels, works out into a moderate and inexpensive cutting in the course of a few miles.

Limit of irrigation reached in a cutting several miles in length.

11. Sir A. Cotton in one of his early reports on the Godavery, thus describes the peculiarities I have mentioned:—"Besides the slope of the land towards the sea in a Delta, it has another slope, viz., a fall from the river in a direction perpendicular to its course, and the fall is much more rapid than that towards the sea. In the present case it has been ascertained to be, near the head of the Delta, 16 feet in two miles from the west, and 7 feet in two and a half miles on the east side. Thirteen miles lower down, that is twenty-

Slope of the country from the bank of the Godavery described by Sir A. Cotton. Professional Papers, Madras Engineers, Vol. III., p. 20.

five miles from the sea, the fall is 9 feet in two and a half miles on the west side of the Godavery. Thus the river banks form a ridge from 18 to 7 feet above the level of the land, at the distance of from three quarters to two and a half miles distant on either side, providing most remarkably for the leading out of the water upon the lands.

“ The apparently formidable operation of bringing the water from the bed of the river is upon an examination of the level reduced to this, that the highest part of the Delta is only 8 or 10 feet above the bed of the river in its immediate neighbourhood, that is within two miles of it, and that if an anicut be built 11 feet high above the deep channel of the river, the deepest excavation for the irrigating channels will be 18 feet, and within two miles, the country on the west side would be below the level of the top of the anicut. On the east side the lands would be on the same level within about four miles. The apparent objection arising from the great depth of the river is thus completely disposed of.”

Ganges canal had to be carried across a number of torrents, or in a very long cutting, before the irrigation limit could be reached.

12. On the Ganges canal the water before reaching the tract of country requiring irrigation, had to be carried across a series of formidable torrents, which required a vast expenditure of time and money. Had the canal been opened from the river below the point where the last of the torrents joins it, it would have had to traverse a distance of 50 or 60 miles before the irrigation limit could be attained. In either case heavy expenditure was necessarily entailed before the water could be turned to any use.

Heads of main channels in the Deltas, simple and inexpensive works, and the length of distribution channels 30 or 40 miles on the average.

13. The main channels in the Godavery and Kistna are simple cuttings, unimpeded by any natural difficulties. Combined with the anicuts, these short cuts carry the water to the points from which it may be distributed to every field in advance, to near the sea, and the distribution channels have not to extend beyond an average distance of 30 or 40 miles.

Ganges canal necessarily of great length.

14. On the Ganges canal the water is conveyed over much more unfavorable ground to a distance of 350 miles from the head. Sir A. Cotton considers this fact, as one of the errors of the original project. The practicability of forming separate heads between Roorkee and Cawnpore in order to reduce the distance to which water is conveyed, without being utilized, forms the subject of separate enquiry. I may remark in this place, that the principal object of the Ganges canal was to ameliorate a famine, and with this object the water was distributed in a certain proportion over a much larger tract of country than was economically necessary. Had it not been for the restriction thus laid on the projector, he could have utilized the whole of the available supply of water in a canal of one-half or one-third the length to which it has been actually carried, and would have had the opportunity of effecting a large saving in the cost of the work.

Vide Sir P. Cantley's Report on Central Dqab Canal, 1840.

Waste land in Deltas.

15. There are several other facts which serve to explain in

some measure the high and quick returns yielded by the Godavery and Kistna works. There is an enormous extent of waste land in the Deltas: the great mass of it is either sandy or more or less swamp, but large tracts not far removed from the sea and recently inundated by it are unfit for cultivation until the soil is improved. Both this and the sandy soil, however, become as valuable as any other land in the Deltas, after several floodings by the river water, loaded as it is with mud of the most fertilizing character.

16. Large tracts are thus rendered productive, which in their natural state were absolutely useless. A further extent of country is brought within the influence of the Delta channels by embanking or draining swamps. It is a common occurrence for 1,000 or even 2,000 acres of such waste land to be taken up in one plot for rice cultivation in a single season; and there is one instance in the Kistna Delta, of the Ryots of a number of villages uniting to present an agreement to take up in one block 15,000 acres of waste land as soon as certain drainage and irrigation channels should be completed, and to pay Government rent for it at the rate of Rs. 6 per acre, or Rs. 90,000 in all per annum.

Large profits derived.

17. This is no exaggeration, as the land was actually taken up on those terms as fast as the drainage and irrigation works progressed. The canals in the N. W. Provinces have no such advantages. Not only is the area of waste cultivable land in the Doab between the Ganges and Jumna of comparatively small extent, but the revenue settlement extends over a period of 30 years, and the cultivator has to pay no more for irrigating waste land, than the small water-rate which he has to pay for land already under cultivation.

No such advantage on the Doab.

18. But on the other hand, high as the returns have been from the Delta works, they would have been far higher had the works experienced a tithe of the liberality with which the Ganges canal has been treated from first to last. Notwithstanding the Government have received incontestible proofs of great and manifold advantages having accrued, both to themselves and to the country, from the extension of irrigation in the Madras presidency, the works which above all others may be taken as the type of what can be accomplished, when a supply of water can be cheaply distributed, are only half finished.

Returns from Deltas retarded by insufficient allotments of funds to complete the works.

19. The Government readily sanction the estimates for the various new works and extensions that are submitted to them, but the money to carry them out is not forthcoming. Not even the modest demands of the local officers for a fixed and regular annual allotment of 5 lakhs of rupees per annum for new works on the Godavery and Kistna united, until the Delta system shall have been fully developed, has been complied with. Channels which may have been in progress in one year, are summarily stopped the next, or if the main channels are completed, the funds required to carry out the minor works, and to turn the others to profitable account may not be granted,

Estimates sanctioned, but money not available to complete various works.

though the works themselves have received the complete approval of Government. Numerous instances could be adduced in which the delay that has thus arisen in utilizing the supply of water, has occasioned a large loss of revenue.

A notice of the grants for expenditure necessary to complete the comparison between Delta works and Ganges canal.

20. I have described the advantages which the Delta works had at starting over the Ganges canal, and to render the comparison a fair one, I think myself bound to take conspicuous notice of this one great disadvantage which they have had to contend against for a long succession of years.

Drainage channels used for irrigation in Deltas, but not in Ganges canal.

21. Many of the drainage channels in the Godavery and Kistna have been used for carrying the water for irrigation. In the country affected by the Ganges canal the drainage courses are deep, and nothing would be gained by using them as irrigation channels. Had they been shallow, the local Engineers would probably still have avoided them, and would have preferred to go to the expense of excavating new channels rather than interfere with the proper function of the drainages. Allowing that there are serious disadvantages in using channels for both purposes, there can be no doubt, that the Engineers in the Godavery and Kistna have secured a large additional revenue by being content to use imperfect channels, when time and money would have been required for the excavation of new ones.

Swamping in Deltas not unhealthy, as it is in the Doab.

22. The slight fall of many portions of the Deltas, combined with the system of using the natural channels for purposes of irrigation, serves to produce extensive swamping; notwithstanding this, it is a remarkable fact, that the Deltas are more healthy than other parts of the district. Fever especially is far less prevalent in the Deltas than in the country immediately beyond it, where there is but little rice cultivation and no swamps. The cause is unknown to me. It can hardly be the influence of the sea air, because the formation of the east coast of India closely resembles that of other countries which are notoriously unhealthy. It is more likely I think to be in the geological formation of the soil. However that may be, it would be useless to attempt to prove that ill-drained rice cultivation in the N. W. Provinces should be healthy because it is healthy in the Madras coast districts.

Few bridges across the Delta channels.

23. There are but few bridges on the Godavery and Kistna canals. In most cases bridges are built over the locks, but on several of the channels there are no bridges for 30 miles and upwards. On the Ganges canal the bridges are built at every two or three miles apart. They have not been constructed in such profusion simply because the Engineers thought them necessary or wished to construct them, but because the Local Government, acting as they would act towards a private company, insisted on having them where communications were intersected.

Small grants of

24. Sir A. Cotton's argument in favor of the procedure which

has been followed in Madras seems a sound one. Doubtless, in some parts of the Deltas, considerable inconvenience is occasioned by the want of bridges, but if only a limited sum was available for expenditure, it was best that it should be used to extend the irrigation.

money considered to be best applied in extending irrigation.

25. The actual want of bridges is not so great in the Deltas as in the N. W. Provinces, for the nature of the soil and absence of suitable material are almost prohibitory to the formation of roads, which should be passable in the rains. Indeed, there are no metalled roads in the Deltas, but the numerous navigable canals supply their place along the principal lines of traffic, and any other traffic is unimportant. In the Ganges and Jumna Doab, there are greater facilities for moving carts; the extent of thickly populated country is much greater; and there is a far higher proportion of important towns and villages, than are to be found in the Godavery and Kistna. Hence, more cross communication is necessary, and we may reasonably expect that bridges at short intervals will be looked upon as a necessary addition to the canals. I may add that the canals in the N. W. Provinces, are rarely closed unless for emergent repairs, when some sacrifice of revenue is likely to be entailed; and that bridges can be built at a considerably less cost in the first instance before water is admitted, than would be possible afterwards.

Bridges required in greater number in the Doab.

26. Thus it appears that a considerable expenditure on account of bridges has to be borne by the Ganges canal, while the Delta channels in Madras are relieved up to this time of any heavy charge on the same account.

Considerable outlay saved to Delta works.

27. In the Godavery and Kistna channels navigation and irrigation can be carried on together more favorably than is possible on the canals in the N. W. Provinces. The principal crop in the Deltas is rice, which requires water from July to December. There is also sugar-cane and a second crop of rice in the Godavery, but the area and quantity of water consumed by them is small compared with the requirements of the others. The channels are aligned with a slight fall, generally from 3 to 6 inches a mile, and locks are placed at such intervals as will allow of still water navigation, when the water is not required for irrigation.

Navigation combined with irrigation in Delta channels, more favorably than is possible in N. W. Provinces.

28. The surface fall of the channels does not necessarily correspond with the fall of the bed. For three or four months in the year, July to October, it may be increased to 9 inches per mile. The velocity, especially in the upper reaches, is then very considerable, and boats cannot work up stream without some difficulty. But for the remaining eight months of the year, a smaller body of water is admitted from the river, and for half that period there is practically still water navigation. On the Ganges canal, on the other hand, the principal demand for water is not during the rains, when the river could supply any quantity that might be required, but during the dry season. Rice is the great staple produce in the South of India, wheat

Large supply of water in Delta channels for only a portion of the year; different circumstances of crop in Delta and the Doab.

that in the N. W. Provinces. The one is raised in the rains, the other in the dry season. The wheat crop on the Jumna canals is greater than all the rain crops united. These canals have been in operation for many years, and rice cultivation has in no way been discouraged, unless near cantonments and large towns; yet it has not extended to such a degree as to require a greater supply of water than the wheat. The following figures which are taken from the last report (for 1864-65) of the Chief Engineer, Irrigation Department, Punjab, serve to show the state of the Irrigation under the Western Jumna canal.

Total number of acres irrigated during 1864-65, 434,965.

Area in acres of the principal crops irrigated for the last five year :—

	1860-61. (Famine year.)	1861-62.	1862-63.	1863-64.	1864-65.
Rice,	44,965	58,578	57,925	47,353	57,157
Cotton,	43,706	33,558	25,549	45,882	77,738
Sugar,	26,102	33,782	44,730	30,089	29,786
Wheat,	1,81,208	1,48,317	1,11,129	1,45,234	1,63,159
	2,95,971	2,74,235	2,39,333	2,68,558	3,27,840

The rice and cotton are rain, or "Khureef" crops. Wheat, dry weather crop, or "Rubbee;" the sugar is irrigated in both seasons.

Discharge of Western Jumna canal during each month.

29. The average monthly discharge of the canal was 1,784 cubic feet per second; 243 acres were therefore irrigated in 1864-65 by each cubic foot per second. The following was the discharge during the different months :—

	Khureef.	Rubbee.
May,	250	November, 2,481·8
June,	1,985·2	December, 1,717·5
July,	2,431·80	January, 482·72
August,	1,559·15	February, 1,532·28
September,	2,265	March, 1,898·05
October,	2,554	April, 2,554
Average,	1,791	1,777

Demand for water as great in dry season as in rains.

30. From the above it appears that the demand for water in April was as great as in July, and in December and March as in August, though July and August are months in which rice requires a plentiful supply of water.

No period of the year available for still water navigation.

31. Instead therefore of the demand for water being fluctuating as is the case in the Delta channels, it is nearly constant throughout

the year, an exceptionally high supply is not wanted owing to the rains; on the contrary the maximum supply required is that yielded by the river during the dry season, and the current will have to be kept up at its maximum during the whole of the period, which on the Godavery and Kistna is available for still or nearly still water navigation.

J. C. ANDERSON, LIEUT.-COLONEL,
Royal Engineers.

A P P E N D I X D.

Note on the deep cutting of the Ganges canal, and the supposed effects of irrigation in the salubrity of the N. W. Provinces.

Deep cutting of the canal imputed as the second fundamental mistake.

1. The second of the fundamental mistakes imputed by Sir Arthur Cotton to the original construction of the Ganges canal is, that the whole of it "has been cut so as to carry the water below the level of the surface, entailing a vast unnecessary expenditure, and keeping the water below the level at which it is required for irrigation; also that in cutting the canal deep in order to prevent the water keeping the neighbouring lands in a wet state, its Engineers produced the very effect they intended to prevent, because they cut through the water-tight stratum, and let the water into the lands below, which carry it all through the country."

2. There can be no doubt that a considerable saving might have been effected by carrying the canal on a higher level and keeping the surface above soil, but as the heads of the rajbuhās or main distributing channels are governed by the levels of the weirs or falls, there does not appear to be any difficulty (except in the Etawah branch) in regard to the irrigation, which commences within 19 miles from the canal head.

The effect considered to be exaggerated.

3. With respect to the evils supposed to be caused by the percolation of the canal water through the sandy soil below the harder upper crust, it seems that this effect has been exaggerated, as no evidence of it appeared along that part of the canal inspected by the Committee; the only appearance of ooze being where the level is high nor was any information received on the subject; but supposing it to be partly true, it cannot possibly extend "all through the country," nor can it cause the formation of swamps likely to influence the salubrity of the district. The general effect of extensive irrigation will no doubt eventually be to raise the spring level of the tract irrigated, but this will not depend on the surface level of the main canal.

Probable results of irrigation in raising the spring level.

Risk of carrying the canal on a high level.

4. On the other hand, there does seem to be no small risk in carrying a large body of water at a considerable elevation for a great distance between embankments, composed of such poor materials as even the best soil of these districts, and as it is very doubtful if it was possible to ensure throughout an impermeable bed, it seems that the deeper cutting although more expensive was the safest plan.

5. In the Delta of the Cauvery the annual rise of the rivers above the level of the country over which they spread is invariably followed by a corresponding appearance of spring water on the adjacent lands, and constant vigilance is required to secure the embankments.

Rise of springs in the Cauvery Delta, consequent on the floods.

6. But it is remarkable that although that Province is more or less inundated for half the year, and extensive swamps are formed along its southern coast, malaria is unknown; a fact as little capable of explanation as the existence of the evil on the rocky uplands of Coimbatore and Mysore, and especially along the banks of the same river Cauvery; and no inference can be fairly drawn from the salubrity of the Southern Deltas and other irrigated districts, to invalidate the common belief in the malaria caused by irrigation in the N. W. Provinces.

Malaria unknown in Tanjore, but commonly believed to result from irrigation in the N. W. Provinces.

E. LAWFORD.

APPENDIX E.

Note on the section of the proposed weirs across the Ganges and Jumna.

This section being avowedly prepared more in conformity with that of the Godavery anicut, than those of weirs in Tanjore and other Southern districts of Madras, I am desirous of explaining my own views on the principal points in which the proposed work differs from the latter.

1st. The depth of the wells. The Madras wells are sunk only 10 feet below the bed of the river, not merely because they are as firm at that depth as if they were carried lower, provided that no scour removes the sand, but on account of the great difficulty and expense of increasing their depth. Experience has however shown that without an almost unlimited supply of rough stone for their protection, it is not safe to rely on this depth, even in the firm coarse sands of the Southern rivers; much less then would it be prudent to do so in the beds of the Ganges and Jumna, consisting of remarkably fine micaceous sand, totally unlike the former, and sinking when wetted under the slightest pressure.

2nd. The breadth of the cut stone apron. This has been fixed at 50 feet, for a dam 9 feet, or with its upper board 12 feet high, and may seem excessive compared to those of the South, which seldom do if ever exceed three or four times the height of the weir. I, however, concur in the proposed plan, because I believe it will often be found impossible to remove the board in time, and then the height of overfall will closely approximate to the same proportion to the apron as in the Southern rivers. This difficulty has been felt at the Godavery anicut. Further, as there is no doubt that the beds of the rivers will become raised even above the height of the weirs, the overfall will in time be extended beyond its first distance, and may act on the rough apron with too great force.

3rd. The rough concrete apron is carried out 120 feet, with 7 feet of depth at the inner, and 3 feet at the outer, edge. With a cut stone apron of 50 feet, I cannot think such a broad mass of rough material beyond will at first be necessary, but considering the nature of the sand already described, and the inferior kind of material of which this part of the work must necessarily be formed, I have no doubt that the aggregate quantity will be required in a year or two, and it ought certainly to be provided for in the estimates.

E. LAWFORD.

APPENDIX F.

ESTIMATE, No. 1, of the probable expense of a channel from the Ganges at Raoli Ghat to join the Ganges Canal, at 116 $\frac{2}{3}$ miles from Hurdwar,

Width, 180 feet, side slopes, 2 to 1; depth of water, 10 feet; embankments, 12 feet wide at crest; 5 feet high above water surface; side slopes, 2 to 1; fall, 5 $\frac{1}{2}$ inches per mile; total length, 70 miles.

	RUPEES.
1. 1 to 9th mile. Depth of cutting varying from 3·5 to 11·5 feet; contents, 81,404,400 cubic feet, at 3 Rs. per 1000,	2,44,213·2
2. 10 to 16th mile. Embankment from 9·5 to 13·75 high; contents, 31,159,920, at Rs. 5 per 1000,	1,55,799·6
3. 17 to 29 $\frac{2}{3}$ th mile, 10 $\frac{2}{3}$ miles. Embankment, average height 19·4 feet; contents, 55,287,672 cubic feet, at Rs. 5 per 1000, ..	2,76,438·4
Concrete wall in centre of bank, at Rs. 6 per running foot, ..	3,36,600·0
2 $\frac{3}{4}$ miles cutting, average depth 8·3 feet; contents, 23,693,243, at Rs. 3 per 1000,	71,079·7
4. 29 $\frac{2}{3}$ mile to 52nd mile. Berms 12 feet wide, three above water; cutting, 10 $\frac{5}{8}$ mile, from 25·2 to 36·4 feet; contents, 418,532,664 cubic feet, at Rs. 5 per 1000,	20,92,663·3
Cutting for 11 miles, from 15 feet to 24·3 feet; contents, 260,973,504 cubic feet, at Rs. 4 per 1000,	10,43,894·0
Embankment across Kala Nuddee, width of crest 20 feet; height 14·6; contents 70,96,320, at Rs. 8 per 1000,	56,770·5
5. 53 to 70th mile. Cutting from 5 to 14 feet; contents, 172,666,560, at Rs. 3 per 1000,	5,17,999·7

ABSTRACT.

	RUPEES.
1 to 9th mile,	2,44,213·2
10 to 16th mile,	1,55,799·6
17 to 29 $\frac{2}{3}$ th mile,	6,84,118·1
29 $\frac{2}{3}$ to 52nd mile,	{ 20,92,663·3
	{ 10,43,894·0
Embanking Kala Nuddee,	56,770·5
53 to 70th mile,	5,17,999·7
	47,95,458·4
Masonry works, 70 miles, at Rs. 15,000 per mile,	10,50,000
	58,45,458·4
Contingencies, at 8 per cent., ..	4,67,636·6
	63,13,095·0
Establishment, at 7 per cent., ..	4,41,916·0
Land, 70 acres per mile, for 70 miles, at Rs. 24,	1,17,600·0
	68,72,611·0

ESTIMATE, No. 2, of the probable cost of constructing a weir across the Ganges at Raoli Ghat, $4\frac{1}{2}$ miles below Sookertal.

I. WEIR.

1. Cut stone floor, $50 \times 1\frac{1}{2} = 75$		
,, $6 \times 2 = 12$		
	—	
	87, at Rs. 2-8 per foot,	217·5
Concrete or brickwork—		
Floor,.. .. $59 \times 4\frac{1}{2} = 265·5$		
Body wall,.. $8 \times 8\frac{1}{2} = 68$		
Rear apron, $120 \times 5 = 600$		
Front, .. $30 \times 7 = 210$		
	—	
	1143·5, at Rs. 30 per 100,	343·05
Wells, .. $3 \times 6 \times 15 = 270$, at Rs. 60,		162·00
		—
	Total, per foot run,.. ..	722·55
	Total for weir, $722·55 \times 4000 =$	28,90,200
Cast-iron standards and planking, .. $5 \times 4000 =$		20,000

II. WING WALLS.

2. Walls, $25 \times \frac{3 + 10}{2} = 162·5$, at Rs. 30,		= 48·75
Wells, $2 \times 6 \times 15 = 180$, at Rs. 60,		= 108·00
Concrete apron, in front, $30 \times 7 = 210$, at Rs. 20 =		42·00
		—
	Total per foot run,	198·75
	Total for wing walls, $198·75 \times 1,600 =$	3,18,000
3. Concrete blocks along foot of embankment through Khadir,		
$5280 \times 7 \times 30 = 11,08,800$, at Rs. 20 per 100,		2,21,760

ABSTRACT.

	RUPEES.
1. Weir,	29,10,200
2. Wing walls,	3,18,000
3. Concrete blocks along embankment, ..	2,21,760
4. Head sluice and under sluices,	2,50,000
Embankment,	50,000
	—
	37,49,960
Add 10 per cent. for contingences, ..	3,74,996
	—
	41,24,956
Establishment, at 7 per cent,	2,88,747
	—
	44,13,703

NOTE.—50 per cent. has been added to ordinary rates for work to be executed in water, to cover cost of temporary embankments, baling, losses from flood, &c., &c. An exceptionally high rate is allowed for well foundations, owing to the depth of their heads below low water.

ESTIMATE, No. 3. Weir and Works, near Rajghat.

CHANNEL.		RUPEES.
51,68,00,000 cubic feet in 36 feet cutting, at Rs. 5 per 1000, ..		25,84,000
38,58,00,000 " 27 " " 4 " ..		15,43,000
10,80,00,000 " 15 " " 3-8 " ..		3,78,000
19,30,00,000 " 10 " " 3 " ..		5,79,000
Bridges 10, at 25,000 each,		2,50,000
Crossing nullahs (4) and passing canal under Futtehghur branch,		4,50,000
		<hr/> 57,84,000
Contingencies, at 8 per cent., ..		4,62,720
		<hr/> 62,46,720
Superintendence, at 7 per cent., ..		4,37,270
		<hr/> 66,83,990
Land, 42 miles, at 70 acres per mile at Rs. 24 per acre, ..		70,560
		<hr/> 67,54,550
WEIR.		
Wells $7 \times 7 \times 7854 \times 3 \times 30 = 450$, at Rs. 30 per 100 cubic feet = Rs.		135-0
Sinking and curbs for ditto, Rs.		90-0
Bhurtpore cut stone apron, $30 \times 2 = 60$		
Weir face, .. $6 \times 3 = 18$		
Coping, $5 \times 3 = 15$		
		<hr/> 93, at Rs. 2-8 = 232-8
Best block kunker, dressed, $20 \times 1'9" = 35$, at Rs. 1 = 35-0		
Second " " $10 \times 1'6" = 15$, at Rs. 0-12 = 11-4		
Rubble masonry under apron, $60 \times 6 = 360$		
" body of weir, $9 \times 8 = 72$		
		<hr/> 432 at $\frac{30}{100} = 130-0$
Dry rubble, down-stream, $90 \times 4 = 360$		
" up " $30 \times 10 = 300$		
		<hr/> 660 at $\frac{15}{100} = 99-0$
Moveable board and posts, per foot run,		5-0
Puddle, per foot run, say,		10-0
		<hr/> Total, per foot run, .. 747-12, say 748

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Length of weir, 4,500, at Rs. 748 per foot,	33,66,000
Sluice and regulator,	2,50,000
Wing walls and lock, 24 feet wide,	1,50,000
Training and protecting banks,	1,00,000
	<hr/>
	38,66,000
Contingencies, at 10 per cent.,	3,86,600
	<hr/>
	42,52,600
Superintendence, at 7 per cent.,	2,97,680
	<hr/>
Total for weir,	45,50,280
Total for channel,	67,53,990
	<hr/>
Total for the whole work,	1,13,04,270

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ESTIMATE, No. 4. Weir and works on the Jumna, for a project to carry 3,300 cubic feet per second.

CHANNEL.			
13,24,22,400	Excavation in 10 feet cutting, at Rs. 3,	3,97,267	
25,87,20,000	„ 14 „ „ 3,	7,76,160	
28,63,66,080	„ 23 „ „ 4,	11,45,464	
Bridges 19, at Rs. 2,000,	.. .. .	3,80,000	
Crossing drainages, .. .. .	.. .. .	1,50,000	
	Total,	<u>28,49,891</u>	
	Contingencies, at 8 per cent., ..	2,27,991	
		<u>30,77,882</u>	
	Superintendence, at 7 per cent., ..	2,15,451	
		<u>32,93,333</u>	
Land, 57 miles, at 64 acres per mile, at Rs. 24 per acre,	}	87,552	33,80,885
Weir, per foot run—			
Cut stone apron,	$50 \times 1\frac{1}{2} = 75$		
Do. front of weir,	$7 \times 2 = 14$		
Do. coping,	$6\cdot5 \times 2 = 13$		
		102 at Rs. 0-12 =	76-8
Wells, including sinking and curbs, &c., 3 × 6 × 15 = 270, } at Rs. 60 per 100,			= 162-0
Rubble rough stone, down-stream, 120 × 5 = 600			
„ „ up „ 30 × 7 = 210			
		810, at Rs. 6 per 100 =	48-9
Rubble masonry,	$59 \times 4\frac{1}{2} = 265$		
	$8 \times 8\frac{1}{2} = 68$		
		333, at Rs. 18 =	60-0
			<u>347-1</u>
Length of weir 2,500, at Rs. 347 per foot, ..		8,67,500	
Moveable board and post, at Rs. 5 per foot run, ..		12,500	
Sluices and regulators,		1,50,000	
Wing walls and two locks,		1,50,000	
Training and protecting banks,		50,000	
	Total,	<u>12,30,000</u>	
	Contingencies, at 10 per cent., ..	1,23,000	
	Total,	<u>13,53,000</u>	
	Superintendence, at 7 per cent., ..	94,000	
	Total,	<u>14,47,000</u>	
Weir and passage over Hindun, including } training and protecting walls,	440,	2,50,000	16,97,000
	Total Rupees, ..		<u>50,77,885</u>
Say, Rs. 51,00,000.			

ESTIMATE, No. 5. Weir and works on the Jumna. Estimate for project to carry 1,500 feet per second.

CHANNEL.						RUPEES.
7,02,25,000	cubic feet in 10 feet cutting, at Rs. 2-8 per 100,					1,75,560
14,41,44,000	„ 14 „ „ 2-8 „					3,60,360
18,09,50,100	„ 23 „ „ 3-8 „					6,33,325
19	bridges, at Rs. 15,000,	..	..	..	..	2,85,000
	Crossing drainages,	..	..	..	..	1,00,000
						<hr/> 15,54,245
	Contingencies, at 8 per cent.,	..	..			1,24,339
						<hr/> 16,78,584
	Superintendence, at 7 per cent.,	..	..			1,17,500
						<hr/> 17,96,084
	Land, 58 miles, at 50 acres per mile, at Rs. 24 per acre,	..				69,600
						<hr/> 18,65,684
	Total for channel,	..				18,65,684
	Total for weir over Jumna and Hindun, as in preceding estimate,	..	..	..	..	17,00,000
						<hr/> 35,65,684
	Total for project,	..				35,65,684

