Public Works (1897) Department.

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Brut
Everett

G.O., No 231 I

DATED 6. march 1897

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[Despatch Abstract.]

Godavari and Kistna Works: Ext of India letter forwarding with remarks a note by the Inspector General of Irrigation relating to the — Coast & with remarks to officers concerned for guidance.

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BACK PAPERS.

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IRRIGATION.

Government {1897} of Madras.

PUBLIC WORKS.

Recd. } 1897. *Enclosures*

Regd. *Spare copies*

G.O., No. 231 I., 6th March 1897.

MARCH.

Godavari and Kistna Works

Government of India letter forwarding, with remarks, a note by the Inspector-General of Irrigation relating to the —, communicated, with remarks, to officers concerned for guidance.

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Irrigation.

Read—the following paper :—

From N. F. MACKENZIE, Esq., Under Secretary to the Government of India, Public Works Department (Civil Works—Irrigation), to the Secretary to the Government of Madras, Public Works Department, dated Calcutta, 4th February 1897, No. 40 I.

I am directed to acknowledge the receipt of the Proceedings of the Government of Madras quoted on the margin, copies forwarded under your Nos. 790 I., and 1000 I., dated, respectively, the 29th September and 27th November 1896, on the subject of the floods in the Kistna river.

No. 789 I., dated 29th September 1896.
No. 999 I., dated 27th November 1896.

2. In reply to your No. 1000 I., I am to say that the Government of India note with satisfaction the approval recorded by His Excellency the Governor in Council of the good work done by Major Baddeley and the officers and subordinates under him during the recent floods.

3. With reference to paragraph 3 of Madras Government Order, No. 789 I., dated the 29th September 1896, I am to refer to Mr. Upcott's report regarding the Kistna railway bridge which was received by the local Government after that letter was issued, and to forward, for the information of your Government, a note by the Inspector-General of Irrigation relating to the Gódávari and Kistna works.

4. As regards the Kistna works, I am to invite attention to paragraphs 6 to 13 of the notes, and to say that the Government of India concur in the opinion that it is unnecessary to lengthen the Bezwada bridge, and they accept the view of the Inspector-General, as expressed in paragraph 10 of his notes, that the raising of the crest of the anicut has been a more important factor of the violent action that occurred below the anicut, and is more likely to cause danger to the work, than the left upstream embankment of the bridge, and that they are of opinion that the upper 2 feet of the raised portion should be at once removed and replaced by falling shutters, and that the apron of the anicut should be extended, as suggested in paragraph 10 of the notes.

As regards the left embankment upstream of the bridge, it should be maintained at the height and section that may be advised by the Irrigation officers.

5. I am also to say that the Government of India consider that the objection to increasing the height of crest of the anicut will apply with almost equal force to the Gódávari anicut, and that, as proposed in paragraph 3 of the inspection notes, shutters should be substituted for the extra 2 feet of masonry which was provided for in the estimate sanctioned by the Government of India in Public Works Department letter, No. 4 I., dated the 13th January 1896.

6. With reference to paragraph 16 of the inspection notes, I am to ask that an estimate for the construction of the lower regulator and connected works on the Sitanagram side may be submitted to the Government of India for sanction at as early a date as practicable, if this is not covered by the current sanction for the Kistna delta system project, and that estimates for the other works noted in that paragraph which it may be proposed to charge against the Capital account of the system, should also be submitted in due course for sanction.

Enclosure.

Note by T. Higham, Esq., Inspector-General of Irrigation.

1. Leaving Rangoon on the 24th November by one of the British India Coasting steamers I arrived at Vizagapatam on the 29th and at once proceeded by rail from Waltair to Rajahmundry (Dowlaishweram) arriving on the following morning.

My subsequent movements were as below :—

Date.	Place.	Principal object of inspection.
November 30th—December 1st ..	Dowlaishweram	Gódávari head works.
December 2nd—4th	Bezwada	Kistna do.
,, 5th—8th	Nandyal to Cuddapah	Kurnool-Cuddapah canal.
,, 9th—11th	Madras	....
,, 12th—16th	Trichinopoly	Cauvery head works.
,, 17th—22nd	To Periyár and back	Periyár works.
,, 23rd	Madras	Had an interview with His Excellency the Governor.

Gódávari Head Works.

2. On the morning of 30th I went up the river and saw the site finally proposed for the East Coast Railway bridge over Gódávari, when I met Mr. Walton. The plans of the river and a note by Mr. Bell were shown to me. It is proposed to cross the river about 2 miles higher up than proposed by Mr. Bell by 57 spans of 150 feet, giving a clear waterway of 8,700 feet. As far as the Gódávari head works are concerned, no objection can be made to these proposals.

3. On 1st December I went over the fine and interesting head works of the Gódávari, and saw the head regulators of the Eastern, Central and Western canals. As the level of anicut crest is not sufficiently high to maintain the supplies required for the canal, rail stanchions about 2 feet high have been fixed into the masonry at intervals of from 8 to 10 feet, and the water level is held up 2 feet by means of planks, which are removed as the river begins to rise. The labour of fixing and removing these planks is very great, there is an immense amount of leakage, while the permanent iron stanchions are very objectionable. An estimate, amounting to Rupees 1,33,000, for raising the crest wall 2 feet was therefore submitted to the Government of India and sanctioned in their letter, No. 4 I., dated 13th January 1896. A few chains only of this work have been done, and I am very strongly of opinion that the work should not be continued. The danger of permanently increasing the height of the anicut, without very large additions to the stone work downstream, has been very clearly shown at Bezwada, and there is the further objection that it causes a shoaling of the river upstream. It will be much better that the extra 2 feet required should be secured by means of falling shutters, or a moveable weir, following the practice which has been adopted on the Sone canals at Dehree, the Lower Ganges canal at Narora, the Agra canal at Okla, the Sirhind canal at Rupar, and the Chenab canal at Khanki, in all of which the full height required is obtained by means of falling shutters, which can be lowered as the river rises. Probably the Sone canal pattern would be found most suitable for Dowlaishweram. The principal difficulty with such shutters is the raising, which is generally effected after laying the crest dry by means of the undersluices. At Dowlaishweram the power of the undersluices is not sufficient for this, but the shutters can no doubt be raised with one foot of water on the crest, and with much less risk and trouble than is involved in the present practice of fixing planks, while they can be designed to fall automatically as the river rises as at Dehree, or under control by means of a let-go arrangement, as at the other head works mentioned above. The former plan will probably be preferred.

Kistna Head Works.

4. The extraordinary flood in the Kistna on the 6th August 1896 was the highest on record, and caused a serious breach 450 feet in length, in the left river embankment above Bezwada, while the right embankment and the important head works of the Kistna canals were in serious danger. The river embankments on both sides below Bezwada were also seriously breached in a great many places.

The maximum flood levels at site of anicut, when at 6 P.M. on night of the 6th August, are shown below, the mean sea level being the datum line. The reduced level of the present crest of anicut is 49·25 feet, while that of the zero of the anicut gauges, the readings of which are quoted in the reports of the Local Officers, is 26·25.

Position of gauge.	Maximum flood level, 1896.			Previous maximum levels, July 1882.
	Left bank, Bezwada.	Right bank, Sitanagram.	Mean.	
Above anicut	67·55	67·55	67·55	66 29
Below anicut	66·25	64·95	65·60	65·50
Afflux ..	1·30	2·60	1·95	·79

The levels for July 1882 are probably the maximum then recorded, and not the mean of right and left banks. As regards the levels downstream of anicut, it will be seen that the maximum of left bank level in 1896 was 0·75 foot above the record of 1882, but if the mean level be taken, the difference is only 0·1 foot. Some heading up probably occurred on these gauges, owing to the obstruction caused by the left bank training works of the railway bridge (a matter to be presently referred to), and allowing for this it is possible that the volume of the flood was not actually much greater than in 1882, though the Executive Engineer has estimated the flood discharge of August 1896 at 762,000 cusecs, against 611,000 in 1882. It may be noted that Colonel Mullins in his "Irrigation Manual" has estimated the two great Kistna floods of 1874 and 1882 at 736,000 and 770,000 cusecs, respectively.

5. In 1882 the upstream gauge on right bank registered 0·66 foot more than that on the left, and if 66·29 be the reading of the former, the mean gauge will have 65·96, against 67·55 in 1896, so that there was an increase of about 1·6 foot in the latter year. This rise may be partly due to a fuller discharge, but it must be attributed mainly to the fact that the crest of the anicut has been lately raised 3 feet, which probably accounts for at least 1 foot of the increased afflux. As at the Gódávari this increase in the height of the anicut has been found necessary to maintain the large supplies now required for the canals, but in the form in which it has been carried out, is open to the most serious objections. The rise of 1 foot or more in the flood level immediately above the anicut is the least of evils resulting from this raising of the crest. The river bed must in time shoal up the level of the new crest, but the worst consequence is the severe action on the anicut due to the increased afflux. There is a sheer drop of 3 feet on to the anicut talus, which has been neither strengthened nor lengthened to resist this heavy action. I am very strongly of opinion that 2 feet at least of the new work should be removed altogether before next flood season. This will leave the crest 1 foot above its old level, which may be accepted if the downstream apron is extended as proposed below. The supply here as at Dowlaishweram should be held up to any higher level required by falling shutters, which can be thrown down whenever floods have to be passed.

6. The total length of the anicut from flank to flank is 3,714 feet, the length exclusive of undersluices, etc., being 3,341 feet. The Bezwada railway bridge is situated about half a mile downstream, and consists of 12 spans of 300 feet each. It is not, however, built opposite the anicut, but as it were *en echelon*, the centre of the bridge being about 250 feet to the south or right of the centre of the anicut. Thus to bring the bridge opposite the anicut, three spans should be taken off the right end and added to the left. As it is, the left undersluices and adjacent length of weir are apparently masked by the left upstream training embankment, which connects the flank of the undersluices with the bridge end. Major Baddeley, the Superintending Engineer, who was on the spot during the high flood of August 6th, has written in very strong terms of the danger to which the anicut is exposed by the existence of this embankment, and has very earnestly recommended that it be removed, and the bridge be lengthened by three spans on the south end, even if the cost be debited to the canal and not to the railway. Mr. Upcott who visited Bezwada on the 20th and 21st August was of opinion that there was no *primâ facie* evidence that the lengthening of the bridge was necessary to ensure the safety of the anicut, and that the case should be more carefully considered when the present state of the river had been more fully examined. One of the principal objects of my visit was therefore the consideration of this important question.

7. Major Baddeley has stated the case for lengthening the bridge in paragraphs 8 to 12 of his letter, No. 1244 K., dated 13th August 1896, and in paragraph 7 of his letter, No. 1826 K., dated 5th October 1896. Briefly, the dangers which he apprehends may be thus stated—

(*a*) Owing to the obstruction caused by the north training embankment and the insufficient waterway of the bridge the river is silting up on both sides, and this silting will continue until the river, unable to discharge freely through the contracted channel, will rise during floods to a dangerous height above and below the anicut.

(*b*) The effect of the contraction at the bridge is to produce back currents and whirlpools which in 1895 scoured out a hole 50 feet deep below the Bezwada undersluices, which will have increased during 1896, and if this works back and takes down the undersluices, a breach into the canal and a total failure of the head works of the Eastern delta system may be anticipated.

8. As regards (*a*) I am of opinion that there are no real grounds for apprehensions. The flood levels abstracted in paragraph 4 above show that the maximum flood level below anicut in 1896 was only 0·75 foot higher than in 1882, while the difference was probably much less if the mean of right and left bank levels be taken. If we assume that this was entirely due to the obstruction downstream and that the flood discharge in 1896 was no greater than in 1882, the effect on the level upstream would be almost inappreciable. As shown in paragraph 5 above, the mean level upstream was only 1·6 foot higher than in 1882, in spite of the fact that the water-way over the anicut had been solidly blocked by the addition of 3 feet on the crest. The effect of a rise of 0·75 foot in the downstream flood level would be not to block the water-way to that extent, but merely to increase *pro tanto* the height of the drowned, and to decrease the

height of the undrowned portions of the discharge over the anicut. The additional afflux due to this cause would be practically unappreciable. If, on the other land, it be true that the volume of the flood discharge was actually greater than in 1882, the higher levels both above and below the anicut will have been partially due to this cause, and the effect of the bridge works will have been by so much even less than indicated above. I am therefore of opinion that any increase in the height of flood levels above the anicut, as compared with those of 1882, that was not due to an increase in the volume of the flood discharge, must be attributed entirely to the raising of the anicut crest, and was wholly independent of any obstruction caused by the bridge works.

If this be admitted, the extent to which silt may have been deposited in any of the spans of the bridge or below the apron near the Bezwada undersluices is immaterial. The only effect of increasing the number of spans would be either to increase these deposits of silt or to decrease the depth of scour in those spans on which the set of a flood may be heaviest. It has not, however, been stated that the maximum scour at the bridge was greater than was contemplated when the bridge was designed, nor is the safety of the bridge now in question. As regards the effect of the bridge on the flood levels immediately below and above the anicut, I have no hesitation in expressing an opinion that the water-way at present provided is sufficient.

9. As regards objection (*b*) it may be noted that in the original design for the bridge it was proposed to build it opposite the anicut. Subsequently the Engineer-in-Chief (Mr. Spring) decided to place it as now built. The papers in the Madras Public Works Secretariat show that the change was approved by the Chief Engineer, Irrigation Works (Mr. Walch), after personally discussing the matter with Mr. Spring. It is evident, too, that the present position was proposed because all the river charts on record showed plainly that the main channel of the river on rounding the Sitanagram bluff had always run in the direction of a line joining the centres of the anicut and bridge as now constructed, and not at a less acute angle with the line of the anicut. The location of the bridge finally adopted involved, therefore, less disturbance of the natural course of the river. It is obvious, however, that water must at all times cross the anicut at right angles, and that in an extraordinary flood like that of August last with 18 feet over the crest of anicut there would be a very strong set in this direction for some distance after passing the crest, so that the short distance of only half a mile between the anicut and the bridge might be insufficient to allow the flood to accommodate itself to the change of direction. The flood waters impinging on this back, and forced suddenly to change their course would naturally produce the strong back currents, eddies and swirls which were seen by the officers on the spot. Mr. Upcott remarks that the contraction of the water-way would, by checking the velocity, prevent these eddies, but the eddies are not a consequence of the high velocities, if uniform, but of the changes and interruptions of velocity resulting from the blocking of the left side of the channel. No doubt eddies are caused by the meeting of the waters passing through the undersluices and over the weir, but these have always existed, and will be no greater on the left than on the right bank, when the conditions in this respect are identical. I see no reason therefore for doubting the assertion of the very competent observers on the spot that, over and above these ordinary eddies, a great back-swirl was set up by the obstruction caused by the left embankment which might, if continued long enough, or if frequently repeated, endanger the safety of the left end of the anicut and undersluices. The existence of such a swirl is clearly indicated by the levels given in paragrah 4, which show that the water on left bank below anicut stood 1·3 foot higher than on right bank. There is of course nothing extraordinary in the level on one bank of a river being slightly higher or lower than that on the other during a high flood, according to the position and volumes of the main currents, but in this case the levels upstream of the anicut were identical (in 1882 there was a difference of 0·66 foot) so that the discharge was as nearly as possible evenly distributed over the whole length of the anicut. The great difference in the levels immediately downstream shows, however, how the water must have piled up above the left embankment, and is a measure of the violent eddies and swirls which must have occurred between the anicut and bridge. The remedy proposed by the Superintending Engineer, to remove the embankment and lengthen the bridge on the north end by three spans would, no doubt, reduce this action, but it is my opinion only on this account, and not because the water-way at the bridge is in itself insufficient, that the lengthening of the bridge can be recommended. The same object might be almost as effectively attained by removing two or three spans from the south, and adding them to the north end, though this would be open to obvious objections on other grounds.

10. There is little doubt that this left embankment tends to set in motion new forces during the flood season which must be reckoned with by those responsible for the safety of the canal head-works, but the question is whether the difficulties cannot be met by some less heroic and expensive measure than that of lengthening the bridge by three spans, which would probably cost something between 7 and 8 lakhs of rupees. It is however first necessary to consider what damage has actually occurred which may be wholly or partially attributed to any change in conditions since the bridge was constructed. Major Baddeley refers only to a hole 50 feet deep which was scoured in 1895 below the apron near the Bezwada undersluices. It may here be noted that the anicut is protected on the downstream side by an apron of loose stone which extends for an average distance of 170 feet beyond the retaining wall at the foot of the talus.

Ever since the construction of the anicut, scour holes have been formed annually downstream of this apron, more especially on the right and left flanks or near the lines of the undersluices. The normal reduced level of the bed beyond this apron is 26·25, and the depths of scour are measured downwards from this datum. Plans and sections showing the positions and depths of these scour holes since January 1891 were examined by me. The hole referred to by Major Baddeley when measured in January 1896 had a length in a direction square to the line of anicut of 330 feet, and a width in a direction parallel with anicut of 400, the maximum depth being 50·3 feet at about the centre of figure, or 160 feet beyond the end of apron, and 200 feet from the dividing wall of the undersluices. In November 1896 the position and dimensions were about the same, but a sounding of 56 feet was recorded. The plans for January 1891 to 1894 show large holes below the flanks only of the weirs. On the right side these holes varied in depth from 50 to 60 feet. On the Bezwada side the scour was much less, being *nil* in January 1893, and never exceeding 35 feet in other years. The exact changes that have since taken place would be conveniently shown by super-imposing on one sheet the plans of successive years, but the conclusion that I derived from an examination of them was that since the construction of the bridge the scour holes on the left flank have increased both in extent and maximum depth (the soundings having increased from 35 to 55 feet), that there are frequent scour holes below the central portion of the anicut of which there were but traces before, and that the depths of scour on right flank have decreased from between 50 and 60 to 40 feet. It is the increased scour on the left flank more particularly that has caused the Superintending Engineer's apprehension, but although it is only right that this matter should be carefully watched, the depths recorded on this side after the great flood of 1896 were less than occurred regularly on right side before the bridge was constructed. Moreover, although the downstream eddies no doubt tend to produce these holes, the severe action on the weir itself, due to the raising of the crest already referred to, has probably been a far more important factor, and until this has been eliminated, by cutting down the crest as proposed in paragraph 5 above, it cannot be said to what extent the action is due to the bridge training works. Finally it may be said that these holes, which occur below all anicuts in sandy beds, are of no importance, however great the depth, provided that they are kept at a sufficient distance from the retaining wall of the *talus*, and are not allowed to cut back. I understand that the practice has been to fill them up with sand only every cold weather to a surface sloping down from the 26·25 feet level. If the apron were extended over this filling for a distance of 30 feet, or to 200 feet beyond the retaining wall, by means of concrete or masonry blocks, 4 feet × 4 feet × 2 feet, built *in situ* and laid to a slope of about 1 in 5, these scour holes would, in my opinion, cease to be a danger to the work. This would take seven rows blocks, costing about Rs. 50 only per run of 4 feet, or Rs. 12·5 per foot run, so that the whole length of anicut could be protected at a cost of not more than Rs. 50,000, which might be expended gradually. This system has been found very successful in Northern India. If preferred, loose stone might be employed, large stones such as these in the present apron being laid over a stratum of small stuff; but in this case the apron should be extended at least 50 feet, and the blocks will, I think, be found more satisfactory.

11. I should mention here that a very nasty hole was scoured in the talus of the anicut, the general dimensions being 75 feet in line of anicut and 45 feet transversely, the depth varying from 1 to 12 feet, and the edge of the hole being only 18 feet from the left undersluices and 15 feet from the wall of the anicut. This hole cannot, however, be attributed to the contraction below the anicut. It did not occur during the high flood when the effects of that contraction would be most marked, but was first observed on the 3rd July when the levels at the upstream and downstream gauges were 55·90 and 50·45, respectively, *i.e.*, when the depth over the anicut was nearly 12 feet less than on August 6th. It was probably due to the displacement of stones by floating timber; an accident to which all weirs are liable. It has been thoroughly repaired, and was filled up with small stone, overlaid with stones 2 feet deep, which were topped with Portland cement concrete 2 feet thick on upstream side tapering down to 2 feet on the downstream.

12. In regard to the penultimate paragraph of Mr. Upcott's report, I understand that Major Baddeley recommended the strengthening of the right embankment because it will be absolutely necessary to maintain it intact unless or until the bridge is lengthened, when it would of course be dismantled. Even if it were decided to lengthen the bridge the work could not be completed before next floods, and in the meanwhile the embankment must be maintained to the height and section that may be advised by the responsible Irrigation Officers.

13. My general conclusion therefore is that there has been no contraction of the water-way at the Bezwada bridge such as would affect appreciably the levels above the anicut. By lengthening the bridge the violent action which now occurs below the left end of the anicut would probably be materially reduced, but there is no evidence that this action has hitherto caused any serious damage, though it may do so in time and must undoubtedly be guarded against. I consider, however, that the safety of the anicut and undersluices will be far more securely assured by cutting down the upper 2 feet of the present crest and strengthening the works in the manner proposed in paragraph 10 above than by lengthening the railway bridge, and this at less than one-tenth the cost, but the left training embankment should be made secure against over-topping by the highest flood and against the violent action that takes place along its water face.

14. It remains to consider what other works are required to ensure the safety of the head-works during an extraordinary flood, and which must be undertaken whether the bridge is lengthened or not. The weak points are the head sluices or regulators on each bank. As regards those on the Sitanagram side or Western Delta Canal, it appears that owing to apprehensions felt as to their safety, a second regulator was commenced in 1895 a chain or two below the existing work so as to take its place in the event of failure. The chamber referred to in paragraph 4 of the Superintending Engineer's No. 1244 K., dated 13th August 1896, is the length of canal lying between the two regulators, and the construction of the retaining walls proposed was in progress during my visit. This lower regulator was only partially completed when the flood occurred, but it was of considerable service, as by the insertion of planks water was held up 2·65 feet in the chamber. The head on the upper regulator was 13·85 feet which is almost as much as it can stand with safety, and if it had not been for the lower regulator, it would have been necessary either to increase this head or to have increased the canal supply from 11·20 to 13·85 feet, which would have increased the number of breaches, and also have brought into the canal a very large quantity of silt. If the lower regulator had been completed, the canal might have been closed altogether or the supply reduced to the minimum required. The work is, however, in active progress and should be completed before next flood season. The other works in the Western Delta head sluice referred to in paragraph 7 of the Superintending Engineer's letter, No. 1244 K., dated 13th August 1896, were also in hand.

15. On the Bezwada or Eastern Delta side there is no second or ancillary regulator, and in order to avoid subjecting the existing regulator to an excessive head the depth of water admitted into the canal as measured on the rear gauge was 12·9 feet, and this has resulted in a very heavy silt deposit in the upper reach of the canal. A second regulator is very necessary on this side, but to construct it on the ordinary pattern with small vents would lead to a great loss of head, which cannot be spared in view of the extensions of irrigation which are contemplated in the Eastern Delta. The Superintending Engineer, therefore, proposes to build two piers in the line of the pier of the existing bridge below the head sluices, with suitable flank walls, and to have three large sluice gates of 40 feet span constructed in accordance with Stoney's patent. This will be more costly than sluices of the ordinary type, but under the conditions that obtain at the site will be the most suitable form of regulator. Unless something of the kind is made, there will always be a danger of the head regulator failing in such a flood as occurred in August last, so that apart from the advantage of being able to control the amount of flood water passed into the canal the matter may be regarded as one of great urgency, and the necessary plans and estimates should be prepared at once. If preferred, the sluices might be constructed on the principle proposed by Colonel Smart referred to in paragraph *infra*, which is said to be less expensive than Stoney's system, and in the situation proposed could certainly be worked without any risk of failure, but this is a detail to be considered when the plans are under preparation.

16. The works required at Bezwada are therefore—

(*a*) Substitution of falling shutters for the upper 2 feet of anicut.
(*b*) Extension of the apron downstream of the anicut and undersluices.
(*c*) Raising and strengthening the left training embankment between anicut and bridge.
(*d*) Completion of the lower regulator and connected works in the Sitanagram side.
(*e*) Construction of a lower regulator on the Bezwada side, consisting of three 40 feet sluices.

Of these (*a*), (*d*) and (*e*) may fairly be charged to the Capital account of the canal, and (*b*) might also be so charged, unless the Local Government prefers to charge it to Revenue. (*c*) should apparently be carried out at the cost of the railway as part of the bridge works.

I understand that no estimate has yet been sanctioned by the Government of India for the work now in progress in the Sitanagram side, and that the outlay already incurred is held under objection. It appears to have been thought that under the orders conveyed in Government of India letter, No. 95 I, dated 18th May 1896, estimates for new works for which no provision was available from the current sanction for the Kistna Canals could not be considered or sanctioned until the construction estimate had been formally closed on 31st March 1898. This is, however, a misapprehension. In the letter referred to the Government of India declined to sanction an addition of Rs. 8,00,000 in a lump sum to the existing sanction for the Kistna canals to provide generally for unforeseen contingencies, but there is nothing in those orders to prevent the submission of specific estimates even before the closing of the construction estimate for works that may be urgently required. Such estimates will be considered on their merits, and if the safety of the canal works is involved, no time should be lost in submitting them for the orders of the Government of India.

ORDER—No. 231 I., dated 6th March 1897.

Communicated to the officers concerned for information and guidance.

2. Estimates will be submitted for providing the Kistna and Gódávari anicuts with falling shutters and for the works referred to in paragraph 6 of Government of India letter, No. 40 I., and paragraph 16 of the Inspector-General's notes at an early date.

3. The Superintending Engineer, II Circle, will report the height and section to which the left embankment upstream of the Kistna bridge should be maintained in view to the necessary arrangements being made in the Railway Branch.

(True Extract.)

Under Secretary to Government,
Irrigation Branch.

To the Chief Engineer for Irrigation.
„ Superintending Engineers, I and II Circles.
„ the Examiner, Public Works Accounts.
„ the Consulting Engineer for Railways.
„ the Revenue Department.

Exd. Shaik Karim.

PUBLIC WORKS DEPARTMENT,

IRRIGATION BRANCH.

Print emergent

PROCEEDINGS OF THE MADRAS GOVERNMENT.

No 231 I dy 6 March 1897

Irrigation

UNDER date the

READ the following

Letter from the Govt:of India---(H.E.NO:40.I.dated 4th February 1897)

Communicated to the officers concerned for information & guidance.

2. Estimates will be submitted for providing the Kistna and Godavari ani -cuts with falling shutters and for the works referred to in para 6 of Government of India letter NO:40.I. & para 16 of the Inspector General's notes at an early date.

3. The Superintending Engineer, Se--cond circle will report the height & section up to which the left embank--ment upstream of the Kistna Bridge should be maintained in view to the necessary arrangements being made in the Railway Branch.

W. Hughes
I.
20297.

To

The Chief Engr:for Irrigation.
" Supg:Engineers, First and Second circles.
" Examiner of P.W.Accounts.
" Consulting Engr: for Railways
" Revenue Department.

Public Works (1897) Department.

CURRENT No. 1418

Order

2

From The Govt: of India
P.W. Deptt:

No. 402

Dated 4.2.97

Received 9.2.97

Enclosures one

Spare copies "

SUBJECT.

Floods in the Kistna Rivers.- Noting with satisfaction the approval recorded by the Govt: of Madras of the good work done by the officers &c in connection with the -

E. I. Form No 1—1,000—27-11-96.

Public Works (1897) Department.

CURRENT No. 1418

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From The Govt: of India
P.W. Deptt:

No. 402

Dated 4.2.97

Received 9.2.97

Enclosures one

Spare copies "

SUBJECT.

Floods in the Kistna Rivers:- Noting with satisfaction the approval ~~of the~~ recorded by the Govt: of Madras of the good work done by the officers &c in connection with the -

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E. I. Form No 1—1,000—27-11-96.

BACK PAPERS.

No.	Date.

FURTHER PAPERS.

No.	Date.

No 75 I 20 1 97 ✓
No 999 1000 I 27 11 96 ✓
No 772 I 17 11 96 ✓
No 789 I 29. 9. 96 ✓
No 790 I 3 2 96 ✓
No 617 I 2 12 95 ✓

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No. 40 I.

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

CIVIL WORKS.

Irrigation.

All communications should be addressed to the Secretary.

To

The Secretary to the Government of Madras

Public Works Department.

Calcutta, the 4th February 1897.

Sir,

I am directed to acknowledge the receipt of the Proceedings of the Government of Madras quoted on the margin, copies forwarded under your Nos. 790 I. and 1000 I., dated respectively, the 29th September and 27th November 1896, on the subject of the Floods in the Kistna River.

No. 789 I., dated 29th September 1896.	
No. 999 I., dated 27th November 1896.	

2. In reply to your No. 1000 I., I am to say that the Government of India note with satisfaction the approval recorded by His Excellency the Governor in Council of the good work done by Major Baddely and the officers and subordinates under him during the recent floods.

3. With reference to paragraph 3 of Madras Government Order No. 789 I., dated the 29th September 1896, I am to refer to Mr. Upcott's report regarding the Kistna Railway bridge which was received by the Local Government after that letter was issued and to forward for the information of your Government a note by the Inspector General of Irrigation relating to the Godavari and Kistna works.

4. As regards the Kistna works, I am to invite attention to paragraphs 6 to 13 of the notes, and to say that the Government of India concur in the opinion that it is unnecessary to lengthen the Bezwada Bridge, and they accept the

view

view of the Inspector General, as expressed in paragraph 10 of his notes, that the raising of the crest of the anicut has been a more important factor of the violent action that occurred below the anicut, and is more likely to cause danger to the work, than the left upstream embankment of the Bridge, and that they are of opinion that the upper 2 feet of the raised portion should be at once removed and replaced by falling shutters, and that the apron of the anicut should be extended, as suggested in paragraph 10 of the notes.

As regards the left embankment upstream of the Bridge, it should be maintained at the height and section that may be advised by the Irrigation Officers.

5. I am also to say that the Government of India consider that the objection to increasing the height of crest of the anicut will apply with almost equal force to the Godavari anicut, and that as proposed in paragraph 3 of the Inspection Notes, shutters should be substituted for the extra 2 feet of masonry which was provided for in the estimate sanctioned by the Government of India in Public Works Department letter No. 4 I., dated the 13th January 1896.

6. With reference to paragraph 16 of the Inspection notes, I am to ask that an estimate for the construction of the lower regulator and connected works on the Sitanagram side may be submitted to the Government of India for sanction at as early a date as practicable, if this is not covered by the current sanction for the Kistna delta system project, and that estimates for the other works noted in that paragraph which it may be proposed to charge against the Capital Account of the System should also be submitted in due course for sanction.

I have the honour to be,
Sir,
Your most obedient servant,

N. F. Mackenzie

Under Secy. to the Govt. of India.

Document accompanying:-

Note by the Inspector General of Irrigation referred to.

R.L.

245. 8

Note by T. Higham, Esq., Inspector General of Irrigation.

1. Leaving Rangoon on the 24th November by one of the British India Coasting Steamers I arrived at Vizagapatam on the 29th and at once proceeded by rail from Waltair to Rajamundri (Dowlaisheram) arriving on the following morning.

My subsequent movements were as below—

Date.	Place.	Principal object of inspection.
November 30th—December 1st	Dowlaisheram . .	Godaveri head works.
December 2nd—4th . .	Bezvada . . .	Kistna ditto.
„ 5th—8th . .	Nandyal to Cuddapah	Kurnool-Cuddapah Canal.
„ 9th—11th . .	Madras . . .	
„ 12th—16th . .	Trichinopoly . .	Cauvery head works.
„ 17th—22nd . .	To Periyar and back .	Periyar works.
„ 23rd . . .	Madras . . .	Had an interview with His Excellency the Governor.

Godaveri Head works.

2. On the morning of 30th I went up the river and saw the site finally proposed for the East Coast Railway bridge over Godaveri, when I met Mr. Walton. The plans of the river and a note by Mr. Bell were shown to me. It is proposed to cross the river about two miles higher up than proposed by Mr. Bell by 57 spans of 150 feet, giving a clear waterway of 8,700 feet. As far as the Godaveri head works are concerned, no objection can be made to these proposals.

3. On 1st December I went over the fine and interesting head works of the Godaveri, and saw the head regulators of the Eastern, Central and Western Canals. As the level of anicut crest is not sufficiently high to maintain the supplies required for the canal, rail stanchions about 2 feet high have been fixed into the masonry at intervals of from 8 to 10 feet, and the water level is held up 2 feet by means of planks, which are removed as the river begins to rise. The labour of fixing and removing these planks is very great, there is an immense amount of leakage, while the permanent iron stanchions are very objectionable. An estimate, amounting to Rs. 1,33,000, for raising the crest wall 2 feet was therefore submitted to the Government of India and sanctioned in their letter No. 4 I., dated 13th January 1896. A few chains only of this work have been done, and I am very strongly of opinion that the work should not be continued. The danger of permanently increasing the height of the anicut, without very large additions to the stone work downstream, has been very clearly shewn at Bezvada, and there is the further objection that it causes a shoaling of the river upstream. It will be much better that the extra 2 feet required should be secured by means of falling shutters, or a moveable weir, following the practice which has been adopted on the Sone Canals at Dehree, the Lower Ganges Canal at Narora, the Agra Canal at Okla, the Sirhind Canal at Rupar, and the Chenab Canal at Khanki, in all of which the full height

required is obtained by means of falling shutters, which can be lowered as the river rises. Probably the Sone Canal pattern would be found most suitable for Dowlaisheram. The principal difficulty with such shutters is the raising, which is generally effected after laying the crest dry by means of the undersluices. At Dowlaisheram the power of the undersluices is not sufficient for this, but the shutters can no doubt be raised with one foot of water on the crest, and with much less risk and trouble than is involved in the present practice of fixing planks, while they can be designed to fall automatically as the river rises as at Dehree, or under control by means of a let-go arrangement, as at the other head works mentioned above. The former plan will probably be preferred.

Kistna Head works.

4. The extraordinary flood in the Kistna on the 6th August 1896 was the highest on record, and caused a serious breach, 450 feet in length in the left river embankment above Bezvada, while the right embankment and the important head works of the Kistna Canals were in serious danger. The river embankments on both sides below Bezvada were also seriously breached in a great many places.

The maximum flood levels at site of anicut, when at 6 P. M. on night of the 6th August, are shown below, the mean sea level being the datum line. The reduced level of the present crest of anicut is 49·25 feet, while that of the zero of the anicut gauges, the readings of which are quoted in the reports of the Local Officers, is 26·25—

Position of Gauge.	Maximum flood level, 1896.			Previous maximum levels, July 1882.
	Left bank, Bezvada.	Right bank, Sitanagram.	Mean.	
Above anicut . . .	67 55	67·55	67·55	66·29
Below anicut . . .	66·25	64·95	65·60	65·50
Afflux .	1·30	2·60	1·95	·79

The levels for July 1882 are probably the maximum then recorded, and not the mean of right and left banks. As regards the levels downstream of anicut, it will be seen that the maximum of left bank level in 1896 was 0·75 feet above the record of 1882, but if the mean level be taken, the difference is only 0·1 feet. Some heading up probably occurred on these gauges, owing to the obstruction caused by the left bank training works of the railway bridge (a matter to be presently referred to), and allowing for this it is possible that the volume of the flood was not actually much greater than in 1882, though the Executive Engineer has estimated the flood discharge of August 1896 at 762,000 cusecs, against 611,000 in 1882. It may be noted that Colonel Mullins in his "Irrigation Manual" has estimated the two great Kistna floods of 1874 and 1882 at 736,000 and 770,000 cusecs, respectively.

5. In 1882 the upstream gauge on right bank registered 0·66 feet more than that on the left, and if 66·29 be the reading of the former, the mean gauge will have 65·96, against 67·55 in 1896, so that there was an increase of about 1·6 feet in the latter year. This rise may be partly due to a fuller discharge, but it must be attributed mainly to the fact that the crest of the anicut has been lately raised 3 feet, which probably accounts for at least 1 foot of the increased afflux. As at the Godaveri this increase in the height of the anicut has been found necessary to maintain the large supplies now required for the canals, but in the form in which it has been carried out is open to the most serious objections. The rise of 1 foot or more in the flood level immediately above the anicut is the least of evils resulting from this raising of the crest. The river bed must in time shoal up the level of the new crest,

but the worst consequence is the severe action on the anicut due to the increased afflux. There is a sheer drop of 3 feet on to the anicut talus, which has been neither strengthened nor lengthened to resist this heavy action. I am very strongly of opinion that 2 feet at least of the new work should be removed altogether before next flood season This will leave the crest 1 foot above its old level, which may be accepted if the downstream apron is extended as proposed below. The supply here as at Dowlaisheram should be held up to any higher level required by falling shutters, which can be thrown down whenever floods have to be passed.

6. The total length of the anicut from flank to flank is 3,714 feet, the length exclusive of undersluices, etc., being 3,341 feet. The Bezvada Railway bridge is situated about half a mile downstream, and consists of 12 spans of 300 feet each. It is not, however, built opposite the anicut, but as it were *en echelon*, the centre of the bridge being about 250 feet to the south or right of the centre of the anicut. Thus to bring the bridge opposite the anicut, three spans should be taken off the right end and added to the left. As it is the left undersluices, and adjacent length of weir are apparently masked by the left upstream training embankment, which connects the flank of the undersluices with the bridge end. Major Baddeley, the Superintending Engineer, who was on the spot during the high flood of August 6th, has written in very strong terms of the danger to which the anicut is exposed by the existence of this embankment, and has very earnestly recommended that it be removed, and the bridge be lengthened by three spans on the south end, even if the cost be debited to the canal and not to the railway. Mr. Upcott who visited Bezvada on the 20th and 21st August was of opinion that there was no *primâ facie* evidence that the lengthening of the bridge was necessary to ensure the safety of the anicut, and that the case should be more carefully considered when the present state of the river had been more fully examined. One of the principal objects of my visit was therefore the consideration of this important question.

7. Major Baddeley has stated the case for lengthening the bridge in paras. 8 to 12 of his letter No. 1244 K., dated 13th August 1896, and in para. 7 of his letter No. 1826 K., dated 5th October 1896. Briefly the dangers which he apprehends may be thus stated—

(*a*) Owing to the obstruction caused by the north training embankment and the insufficient waterway of the bridge the river is silting up on both sides, and this silting will continue until the river, unable to discharge freely through the contracted channel, will rise during floods to a dangerous height above and below the anicut.

(*b*) The effect of the contraction at the bridge is to produce back currents and whirlpools which in 1895 scoured out a hole 50 feet deep below the Bezvada undersluices, which will have increased during 1896, and if this works back and takes down the undersluices a breach into the canal and a total failure of the headworks of the Eastern Delta system may be anticipated.

8. As regards (*a*) I am of opinion that there are no real grounds for apprehensions. The flood levels abstracted in para. 4 above shew that the maximum flood level below anicut in 1896 was only 0·75 feet higher than in 1882 while the difference was probably much less if the mean of right and left bank levels be taken. If we assume that this was entirely due to the obstruction downstream and that the flood discharge in 1896, was no greater than in 1882, the effect on the level upstream would be almost inappreciable. As shewn in para. 5 above the mean level upstream was only 1·6 feet higher than in 1882, in spite of the fact that the water-way over the anicut had been solidly blocked by the addition of 3 feet on the crest. The effect of a rise of 0·75 feet in the downstream flood level would be not to block the water-way to that extent but merely to increase *pro tanto* the height of the drowned, and to decrease the height of the undrowned portions of the discharge over the anicut. The additional afflux due to this cause would be practically unappreciable. If, on the other hand, it be true that the volume of the flood discharge was actually greater than in 1882, the higher levels both above and

below the anicut will have been partially due to this cause, and the effect of the bridge works will have been by so much even less than indicated above. I am therefore of opinion that any increase in the height of flood levels above the anicut, as compared with those of 1882, that was not due to an increase in the volume of the flood discharge, must be attributed entirely to the raising of the anicut crest, and was wholly independent of any obstruction caused by the bridge works.

If this be admitted the extent to which silt may have been deposited in any of the spans of the bridge or below the apron near the Bezvada undersluices is immaterial. The only effect of increasing the number of spans would be either to increase these deposits of silt or to decrease the depth of scour in those spans on which the set of a flood may be heaviest. It has not, however, been stated that the maximum scour at the bridge was greater than was contemplated when the bridge was designed, nor is the safety of the bridge now in question. As regards the effect of the bridge on the flood levels immediately below and above the anicut, I have no hesitation in expressing an opinion that the water-way at present provided is sufficient.

9. As regards objection (5) it may be noted that in the original design for the bridge it was proposed to build it opposite the anicut. Subsequently the Engineer-in-Chief (Mr. Spring) decided to place it as now built. The papers in the Madras Public Works Secretariat show that the change was approved by the Chief Engineer, Irrigation Works (Mr. Walch), after personally discussing the matter with Mr. Spring. It is evident, too, that the present position was proposed because all the river charts on record showed plainly that the main channel of the river on rounding the Sitanagram bluff had always run in the direction of a line joining the centres of the anicut and bridge as now constructed, and not at a less acute angle with the line of the anicut. The location of the bridge finally adopted involved, therefore, less disturbance of the natural course of the river. It is obvious, however, that water must at all times cross the anicut at right angles [illegible] extraordinary flood like that of August last with 18 feet over the crest of anicut there would be a very strong set in this direction for some distance after passing the crest, so that the short distance of only half a mile between the anicut and the bridge might be insufficient to allow the flood to accommodate itself to the change of direction. The flood waters impinging on this back, and forced suddenly to change their course would naturally produce the strong back currents, eddies and swirls which were seen by the officers on the spot. Mr. Upcott remarks that the contraction of the water-way would, by checking the velocity, prevent these eddies, but the eddies are not a consequence of the high velocities, if uniform, but of the changes and interruptions of velocity resulting from the blocking of the left side of the channel. No doubt eddies are caused by the meeting of the waters passing through the undersluices and over the weir, but these have always existed, and will be no greater on the left than on the right bank, when the conditions in this respect are identical. I see no reason therefore for doubting the assertion of the very competent observers on the spot that, over and above these ordinary, eddies a great back-swirl was set up by the obstruction caused by the left embankment which might, if continued long enough, or if frequently repeated, endanger the safety of the left end of the anicut and undersluices. The existence of such a swirl is clearly indicated by the levels given in para. 4, which shew that the water on left bank below anicut stood 1·3 feet higher than on right bank. There is of course nothing extraordinary in the level on one bank of a river being slightly higher or lower than that on the other during a high flood, according to the position and volumes of the main currents, but in this case the levels upstream of the anicut were identical (in 1882 there was a difference of 0·66 feet) so that the discharge was as nearly as possible evenly distributed over the whole length of the anicut. The great difference in the levels immediately downstream shews, however, how the water must have piled up above the left embankment, and is a measure of the violent eddies and swirls which must have occurred between the anicut and bridge. The remedy proposed by the Superintending Engineer, to remove the embankment and lengthen the bridge on the north end by three spans would, no doubt, reduce this action, but it is my

opinion only on this account, and not because the water-way at the bridge as in itself insufficient, that the lengthening of the bridge can be recommended. The same object might be almost as effectively attained by removing two or three spans from the south, and adding them to the north end, though this would be open to obvious objections on other grounds.

10. There is little doubt that this left embankment tends to set in motion new forces during the flood season which must be reckoned with by those responsible for the safety of the canal head-works, but the question is whether the difficulties cannot be met by some less heroic and expensive measure than that of lengthening the bridge by three spans, which would probably cost nothing between 7 and 8 lakhs of rupees. It is however first necessary consider what damage has actually occurred which may be wholly or partially buted to any change in conditions since the bridge was constructed. r Baddeley refers only to a hole 50 feet deep which was scoured in 1895 the apron near the Bezvada undersluices. It may here be noted that nicut is protected on the downstream side by an apron of loose stone extends for an average distance of 170 feet beyond the retaining wall foot of the talus. Ever since the construction of the anicut scour ve been formed annually downstream of this apron, more especially ht and left flanks or near the lines of the undersluices. The normal vel of the bed beyond this apron is 26·25, and the depths of scour ured downwards from this datum. Plans and sections shewing ns and depths of these scour holes since January 1891 were examined The hole referred to by Major Baddeley when measured in January a length in a direction square to the line of anicut of 330 feet, and a direction parallel with anicut of 400, the maximum depth being at about the centre of figure, or 160 feet beyond the end of apron, eet from the dividing wall of the undersluices. In November 1896 tion and dimensions were about the same, but a sounding of 56 feet rded. The plans for January 1891 to 1894 shew large holes below the nly of the weirs. On the right side these holes varied in depth from 60 feet. On the Bezvada side the scour was much less, being nil in ry 1893, and never exceeding 35 feet in other years. The exact changes ave since taken place would be conveniently shewn by super-imposing on sheet the plans of successive years, but the conclusion that I derived from amination of them was that since the construction of the bridge the scour s on the left flank have increased both in extent and maximum depth soundings having increased from 35 to 55 feet), that there are frequent r holes below the central portion of the anicut of which there were but es before, and that the depths of scour on right flank have decreased from ween 50 and 60 to 40 feet. It is the increased scour on the left flank more ticularly that has caused the Superintending Engineer's apprehension, but hough it is only right that this matter should be carefully watched the pths recorded on this side after the great flood of 1896 were less than occurred gularly on right side before the bridge was constructed. Moreover although e downstream eddies no doubt tend to produce these holes the severe action the weir itself, due to the raising of the crest already referred to, has probably been a far more important factor, and until this has been eliminated, y cutting down the crest as proposed in para. 5 above, it cannot be said to what extent the action is due to the bridge training works. Finally it may be said that these holes, which occur below all anicuts in sandy beds, are of no importance, however great the depth, provided that they are kept at a sufficient distance from the retaining wall of the *talus*, and are not allowed to cut back. I understand that the practice has been to fill them up with sand only every cold weather to a surface sloping down from the 26·25 feet level. If the apron were extended over this filling for a distance of 30 feet, or to 200 feet beyond the retaining wall, by means of concrete or masonry blocks, 4 feet × 4 feet × 2 feet, built *in situ* and laid to a slope of about 1 in 5, these scour holes would, in my opinion, cease to be a danger to the work. This would take seven rows blocks, costing about Rs. 50 only per run of 4 feet, or Rs. 12·5 per foot run, so that the whole length of anicut could be protected at a cost of not more than Rs. 50,000, which might be expended gradually. This system has

below the anicut will have been partially due to this cause, and the effect of the bridge works will have been by so much even less than indicated above. I am therefore of opinion that any increase in the height of flood levels above the anicut, as compared with those of 1882, that was not due to an increase in the volume of the flood discharge, must be attributed entirely to the raising of the anicut crest, and was wholly independent of any obstruction caused by the bridge works.

If this be admitted the extent to which silt may have been deposited in any of the spans of the bridge or below the apron near the Bezvada undersluices is immaterial. The only effect of increasing the number of spans would be either to increase these deposits of silt or to decrease the depth of scour in those spans on which the set of a flood may be heaviest. It has not, however, been stated that the maximum scour at the bridge was greater than was contemplated when the bridge was designed, nor is the safety of the bridge now in question. As regards the effect of the bridge on the flood levels immediately below and above the anicut, I have no hesitation in expressing an opinion that the water-way at present provided is sufficient.

9. As regards objection (*b*) it may be noted that in the original design for the bridge it was proposed to build it opposite the anicut. Subsequently the Engineer-in-Chief (Mr. Spring) decided to place it as now built. The papers in the Madras Public Works Secretariat show that the change was approved by the Chief Engineer, Irrigation Works (Mr. Walch), after personally discussing the matter with Mr. Spring. It is evident, too, that the present position was proposed because all the river charts on record shewed plainly that the main channel of the river on rounding the Sitanagram bluff had always run in the direction of a line joining the centres of the anicut and bridge as now constructed, and not at a less acute angle with the line of the anicut. The location of the bridge finally adopted involved, therefore, less disturbance of the natural course of the river. It is obvious, however, that water must at all times cross the anicut at right angles, and that in an extraordinary flood like that of August last with 18 feet over the crest of anicut there would be a very strong set in this direction for some distance after passing the crest, so that the short distance of only half a mile between the anicut and the bridge might be insufficient to allow the flood to accommodate itself to the change of direction. The flood waters impinging on this back, and forced suddenly to change their course would naturally produce the strong back currents, eddies and swirls which were seen by the officers on the spot. Mr. Upcott remarks that the contraction of the water-way would, by checking the velocity, prevent these eddies, but the eddies are not a consequence of the high velocities, if uniform, but of the changes and interruptions of velocity resulting from the blocking of the left side of the channel. No doubt eddies are caused by the meeting of the waters passing through the undersluices and over the weir, but these have always existed, and will be no greater on the left than on the right bank, when the conditions in this respect are identical. I see no reason therefore for doubting the assertion of the very competent observers on the spot that, over and above these ordinary, eddies a great back-swirl was set up by the obstruction caused by the left embankment which might, if continued long enough, or if frequently repeated, endanger the safety of the left end of the anicut and undersluices. The existence of such a swirl is clearly indicated by the levels given in para. 4, which shew that the water on left bank below anicut stood 1·3 feet higher than on right bank. There is of course nothing extraordinary in the level on one bank of a river being slightly higher or lower than that on the other during a high flood, according to the position and volumes of the main currents, but in this case the levels upstream of the anicut were identical (in 1882 there was a difference of 0·66 feet) so that the discharge was as nearly as possible evenly distributed over the whole length of the anicut. The great difference in the levels immediately downstream shews, however, how the water must have piled up above the left embankment, and is a measure of the violent eddies and swirls which must have occurred between the anicut and bridge. The remedy proposed by the Superintending Engineer, to remove the embankment and lengthen the bridge on the north end by three spans would, no doubt, reduce this action, but it is my

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opinion only on this account, and not because the water-way at the bridge as in itself insufficient, that the lengthening of the bridge can be recommended. The same object might be almost as effectively attained by removing two or three spans from the south, and adding them to the north end, though this would be open to obvious objections on other grounds.

10. There is little doubt that this left embankment tends to set in motion new forces during the flood season which must be reckoned with by those responsible for the safety of the canal head-works, but the question is whether the difficulties cannot be met by some less heroic and expensive measure than that of lengthening the bridge by three spans, which would probably cost something between 7 and 8 lakhs of rupees. It is however first necessary to consider what damage has actually occurred which may be wholly or partially attributed to any change in conditions since the bridge was constructed. Major Baddeley refers only to a hole 50 feet deep which was scoured in 1895 below the apron near the Bezvada undersluices. It may here be noted that the anicut is protected on the downstream side by an apron of loose stone which extends for an average distance of 170 feet beyond the retaining wall at the foot of the talus. Ever since the construction of the anicut scour holes have been formed annually downstream of this apron, more especially on the right and left flanks or near the lines of the undersluices. The normal reduced level of the bed beyond this apron is 26·25, and the depths of scour are measured downwards from this datum. Plans and sections shewing the positions and depths of these scour holes since January 1891 were examined by me. The hole referred to by Major Baddeley when measured in January 1896 had a length in a direction square to the line of anicut of 330 feet, and a width in a direction parallel with anicut of 400, the maximum depth being 50·3 feet at about the centre of figure, or 160 feet beyond the end of apron, and 200 feet from the dividing wall of the undersluices. In November 1896 the position and dimensions were about the same, but a sounding of 56 feet was recorded. The plans for January 1891 to 1894 shew large holes below the flanks only of the weirs. On the right side these holes varied in depth from 50 to 60 feet. On the Bezvada side the scour was much less, being nil in January 1893, and never exceeding 35 feet in other years. The exact changes that have since taken place would be conveniently shewn by super-imposing on one sheet the plans of successive years, but the conclusion that I derived from an examination of them was that since the construction of the bridge the scour holes on the left flank have increased both in extent and maximum depth (the soundings having increased from 35 to 55 feet), that there are frequent scour holes below the central portion of the anicut of which there were but traces before, and that the depths of scour on right flank have decreased from between 50 and 60 to 40 feet. It is the increased scour on the left flank more particularly that has caused the Superintending Engineer's apprehension, but although it is only right that this matter should be carefully watched the depths recorded on this side after the great flood of 1896 were less than occurred regularly on right side before the bridge was constructed. Moreover although the downstream eddies no doubt tend to produce these holes the severe action on the weir itself, due to the raising of the crest already referred to, has probably been a far more important factor, and until this has been eliminated, by cutting down the crest as proposed in para. 5 above, it cannot be said to what extent the action is due to the bridge training works. Finally it may be said that these holes, which occur below all anicuts in sandy beds, are of no importance, however great the depth, provided that they are kept at a sufficient distance from the retaining wall of the *talus*, and are not allowed to cut back. I understand that the practice has been to fill them up with sand only every cold weather to a surface sloping down from the 26·25 feet level. If the apron were extended over this filling for a distance of 30 feet, or to 200 feet beyond the retaining wall, by means of concrete or masonry blocks, 4 feet × 4 feet × 2 feet, built *in situ* and laid to a slope of about 1 in 5, these scour holes would, in my opinion, cease to be a danger to the work. This would take seven rows blocks, costing about Rs. 50 only per run of 4 feet, or Rs. 12·5 per foot run, so that the whole length of anicut could be protected at a cost of not more than Rs. 50,000, which might be expended gradually. This system has

been found very successful in Northern India. If preferred, loose stone might be employed, large stones such as these in the present apron being laid over a stratum of small stuff but in this case the apron should be extended at least 50 feet, and the blocks will, I think, be found more satisfactory.

11. I should mention here that a very nasty hole was scoured in the talus of the anicut, the general dimensions being 75 feet in line of anicut and 45 feet transversely, the depth varying from 1 to 12 feet, and the edge of the hole being only 18 feet from the left undersluices and 15 feet from the wall of the anicut. This hole cannot, however, be attributed to the contraction below the anicut. It did not occur during the high flood when the effects of that contraction would be most marked, but was first observed on the 3rd July when the levels at the upstream and downstream gauges were 55·90 and 50·45, respectively, *i. e.*, when the depth over the anicut was nearly 12 feet less than on August 6th. It was probably due to the displacement of stones by floating timber; an accident to which all weirs are liable. It has been thoroughly repaired, and was filled up with small stone, overlaid with stones 2 feet deep, which were topped with Portland cement concrete 2 feet thick on upstream side tapering down to 2 foot on the downstream.

12. In regard to the penultimate paragraph of Mr. Upcott's report, I understand that Major Baddeley recommended the strengthening of the right embankment because it will be absolutely necessary to maintain it intact unless or until the bridge is lengthened, when it would of course be dismantled. Even if it were decided to lengthen the bridge the work could not be completed before next floods, and in the meanwhile the embankment must be maintained to the height and section that may be advised by the responsible Irrigation Officers.

13. My general conclusion therefore is that there has been no contraction of the water-way at the Bezvada bridge such as would affect appreciably the levels above the anicut. By lengthening the bridge the violent action which now occurs below the left end of the anicut would probably be materially reduced, but there is no evidence that this action has hitherto caused any serious damage, though it may do so in time and must undoubtedly be guarded against. I consider however that the safety of the anicut and undersluices will be far more securely assured by cutting down the upper 2 feet of the present crest and strengthening the works in the manner proposed in para. 10 above, than by lengthening the railway bridge, and this at less than one-tenth the cost, but the left training embankment should be made secure against over-topping by the highest flood and against the violent action that takes place along its water face.

14. It remains to consider what other works are required to ensure the safety of the headworks during an axtraordinary flood, and which must be undertaken whether the bridge is lengthened or not. The weak points are the head sluices or regulators on each bank. As regards those on the Sitanagram side or Western Delta Canal, it appears that owing to apprehensions felt as to their safety, a second regulator was commenced in 1895 a chain or two below the existing work so as to take its place in the event of failure. The chamber referred to in para. 4 of the Superintending Engineer's No. 1244 K., dated 13th August 1896, is the length of canal lying between the two regulators, and the construction of the retaining walls proposed was in progress during my visit. This lower regulator was only partially completed when the flood occurred, but it was of considerable service, as by the insertion of planks water was held up 2·65 feet in the chamber. The head on the upper regulator was 13·85 feet which is almost as much as it can stand with safety, and if it had not been for the lower regulator it would have been necessary either to increase this head or to have increased the canal supply from 11·20 to 13·85 feet, which would have increased the number of breaches, and also have brought into the canal a very large quantity of silt. If the lower regulator had been completed, the canal might have been closed altogether or the supply reduced to the minimum required. The work is, however, in active progress and should be completed before next flood season. The other works in the Western Delta

head sluice referred to in para. 7 of the Superintending Engineer's letter No. 1244 K., dated 13th August 1896, were also in hand.

15. On the Bezvada or Eastern Delta side there is no second or ancillary regulator, and in order to avoid subjecting the existing regulator to an excessive head the depth of water admitted into the canal as measured on the rear gauge was 12·9 feet, and this has resulted in a very heavy silt deposit in the upper reach of the canal. A second regulator is very necessary on this side, but to construct it on the ordinary pattern with small vents would lead to a great loss of head, which cannot be spared in view of the extensions of irrigation which are contemplated in the Eastern Delta. The Superintending Engineer, therefore, proposes to build two piers, in the line of the piers of the existing bridge below the head sluices, with suitable flank walls, and to have three large sluice gates of 40 feet span, constructed in accordance with Stoney's patent. This will be more costly than sluices of the ordinary type, but under the conditions that obtain at the site will be the most suitable form of regulator. Unless something of the kind is made, there will always be a danger of the head regulator failing in such a flood as occurred in August last, so that apart from the advantage of being able to control the amount of flood water passed into the canal the matter may be regarded as one of great urgency, and the necessary plans and estimates should be prepared at once. If preferred, the sluices might be constructed on the principle proposed by Colonel Smart referred to in para. *infra*, which is said to be less expensive than Stoney's system, and in the situation proposed could certainly be worked without any risk of failure, but this is a detail to be considered when the plans are under preparation.

16. The works required at Bezvada are therefore—

(*a*) Substitution of falling shutters for the upper 2 feet of anicut.

(*b*) Extension of the apron downstream of the anicut and undersluices.

(*c*) Raising and strengthening the left training embankment between anicut and bridge.

(*d*) Completion of the lower regulator and connected works in the Sitanagram side.

(*e*) Construction of a lower regulator on the Bezvada side, consisting of three 40 feet sluices.

Of these (*a*), (*a*) and (*e*) may fairly be charged to the Capital account of the canal, and (*b*) might also be so charged, unless the Local Government prefers to charge it to Revenue. (*c*) should apparently be carried out at the cost of the railway, as part of the bridge works.

I understand that no estimate has yet been sanctioned by the Government of India for the work now in progress in the Sitanagram side, and that the outlay already incurred is held under objection. It appears to have been thought that under the orders conveyed in Government of India letter No. 95 I., dated 18th May 1896, estimates for new works for which no provision was available from the current sanction for the Kistna Canals could not be considered or sanctioned until the construction estimate had been formally closed on 31st March 1898. This is, however, a misapprehension. In the letter referred to the Government of India declined to sanction an addition of Rs. 8,00,000 in a lump sum to the existing sanction for the Kistna Canals to provide generally for unforeseen contingencies, but there is nothing in those orders to prevent the submission of specific estimates even before the closing of the construction estimate for works that may be urgently required. Such estimates will be considered on their merits, and if the safety of the canal works is involved, no time should be lost in submitting them for the orders of the Government of India.