Revenue (1897) Department.

ROUTINE SERIES.

G.O., No. 2329

DATED 15th Dec.

[Despatch Abstract.]

Recording Proc: of the P.W.D. awaiting the submission of estimates for certain ~~temple~~ works in connection with the Periyar main dam referred to in his note by the Chief Engineer for Irrigation & directing that the G of I may be addressed on the subject of the Periyar scheme.

BACK PAPERS.

G.O.	No.	Department.	Date.	G.O.	No.	Department.	Date.

FURTHER PAPERS.

G.O.	No.	Department.	Date.	G.O.	No.	Department.	Date.

Revenue 1897 Department

Irrigation

IRRIGATION.

Government {1897} of Madras.

PUBLIC WORKS.

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G.O., No. 992 I., 10th November 1897.

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Recorded.

Wks 17/12/97

17 Copy to the Board of Rev., Rev. Sett. Dep. 16.12.97

C.R. 17/12/97

Periyar escape.

Awaiting the submission of estimates for certain works in connection with the Periyár main dam referred to in his note by the Chief Engineer for Irrigation, and directing that the Government of India be addressed on the subject of the —.

P.C. 13/12/97

11/12/97

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Irrigation.

READ—the following paper:—

No. 228 I.

Note by the Chief Engineer for Irrigation.

With reference to the Inspector-General's notes on the "Periyár canal" received with the Government of India letter, No. 128 I.,* dated 1st May 1897, the following information is submitted.

* Printed with P.M.G., No. 550 I., dated 14th June 1897.

In the absence of any record of the reasons for considering that the right bank escape—length 434 feet—provided sufficient means of discharging surplus from the lake, Mr. Pears, who was Executive Engineer and Superintendent of Works, during the greater part of the time the works were in progress and up to the time of their completion, was written to. His reply is as follows:—

For many years Colonel Pennycuick has been of opinion that his estimate of the flood of November of 1869 is much in excess of the reality. During the nine years that the works were in progress the biggest flood was that of 24th July 1892, which was only 25,000 cubic feet per second, or one-fifth of the supposed flood of 1869. No other flood, while we were there (except—*for a few hours only*—that of December 31st, 1895), ever approached this figure, which confirmed Colonel Pennycuick in his belief. Consequently when, in May 1895, we were driven to make a bund at the left flank instead of the originally-intended left bank escape, Colonel Pennycuick decided that the right bank escape would form a sufficient provision for floods. With 16 feet depth and an excellent fall in rear, the velocity would be about 10 feet per second, which gives a discharge of 420 × 16 × 10 = 67,200 cubic feet per second for the right bank escape alone. When the main dam was nearing completion, I proposed to fix its crest (top of parapet walls) at 158 instead of 160, or 2 feet lower than the crest of the masonry part of the left bank extension. This was accordingly done and a depth of 2 feet will surplus over the main dam before the left bank extension is topped. This gives another 8,000 cubic feet per second or so, or about 75,000 cubic feet per second altogether, exclusive of the trifle discharged by the tunnel.

The only actual reason why the surplussing power was reduced was the discovery of the fault in the foundation of the left bank escape. This forced us to abandon the idea of using it as an escape and we accepted the right bank escape as sufficient—supplemented by the slight lowering of the dam as above-mentioned rather than face the problem of providing a substitute for the abandoned left bank escape: it was very doubtful whether such a substitute was wanted at all, and it could only be provided at great expense.

The whole question is "how much reliance can be placed on the record of the 1869 flood." Wipe out that record altogether on the one hand, and no one would doubt, that the present surplusage is ample, seeing that it provides for three times as much as any other flood on record. Accept it as authentic, on the other hand, and it is certain that the left bank extension is doomed, and it is only a question of whether it will be breached this year or twenty years hence.

My own opinion is that the flood of 1869 was nothing like the Blue-book figure. The flood of July 1892 was produced by a rainfall of 6·80 inches in less than 12 hours; the flood of 1869 was produced by a rainfall of 28 inches in (I write from memory) 24 hours (or was it an even longer time?). It is impossible to think that this can have brought down a flood five times as big as the other. Moreover, knowing as I do how even a 5,000 feet flood filled the river bed "up to the brim," I feel sure that if 30,000 or 40,000 feet floods were of even occasional occurrence, the permanent channel would be far bigger than it is. Therefore, it would be a great surprise to me to hear of the lake filling to even 158. I feel tolerably easy as to the sufficiency of the surplusage and would not recommend any large expenditure, as for instance, widening the right bank escape. On the other hand, I have a great respect for the Periyár river having so often seen our prophecies upset by it, and therefore, if by spending Rs. 500 or so on demolishing the middle part of the parapets of the main dam, you can get rid of another five or six thousand cubic feet per second, I should certainly call it a wise thing to do as a provision against the unexpected.

2. The difficulties met with in attempting to build the left bank escape as designed, are fully described in Colonel Pennycuick's note on the progress report for March 1895, printed with G.O., No. 448 I., dated 30th May 1895. He decided to build the escape only as far as the fault discovered in the rock and to build at its end a massive wing-wall connected with the hill by an earthen bund. It was

subsequently found that the rear wing could not be built, and it was then arranged to raise what had been built of the escape to the level of the main dam. Regarding this, Colonel Pennycuick says in his note on the progress report for August 1895, printed with G.O., No. 799 I., dated 30th September 1895:

4. The extension of the fault in rear of the left bank escape compels the adandonment of the idea of using this portion of the work for the discharge of flood water, for though the wall itself is on perfectly sound rock, the fault is so close to its foot that it would be hardly safe to allow water to fall on it from a height of more than 40 feet.

5. This being so, it will not be necessary to build the rear wing wall to the earthen bank at the south end of the dam and the bank may be allowed to slope in rear of the dam, which will be raised to the same height as the main dam. The necessary instructions have been given.

6. The matter is of no practical importance as I have never attached any great value to the use of this supplemental escape, the main escape on the right bank being amply sufficient.

3. The above is all there is on record. It is scarcely right to speak of the left escape as a supplemental one since it was to be the larger of the two, 500 feet against 420, and its discharging capacity for any given level would have been 60 per cent. of the whole as the right bank escape is some hundreds of feet in width from front to rear at sill level which greatly impairs its efficiency. There is nothing to show the result anticipated from this great reduction of the escapes or the reason for Colonel Pennycuick's disbelief in the calculations of discharges in the flood of October 1869. As he must have known how the calculations were made and in what respects they are likely to be faulty, it is unfortunate he has not recorded his reasons for rejecting them. No record of the gaugings can be found except that given in the Blue-book, but the subject is so important and demands such full discussion that an attempt has been made to obtain records of high floods elsewhere and see if they throw any light upon the question.

4. The maximum rate of flow and the total flow from a catchment basin depend on—

First—The period and intensity of rainfall.
Second—The lie of the country with reference to direction of storms.
Third—Area and form of the basin.
Fourth—Slope.
Fifth—Vegetation.
Sixth—The degree of saturation previous to a storm.

On examining the map (tracing attached), it will be seen that the Periyár valley lies immediately west of the watershed between Tinnevelly and Travancore. Its length is only some 30 miles, extreme width 15, and average width 10 miles. The hills on the watershed are from 4,000 to 6,000 above sea, and the lake level nearly 3,000 feet, with neighbouring hills rising a few hundred feet higher. The lower parts of the hills are for the most part clothed with long grass with patches of jungle, but the higher parts are steep and rocky with no great depth of soil. The average rainfall is not known, but is evidently much greater than at the places where rain gauges have been kept. Colonel Pennycuick believed it to be about 90 inches. In a discussion at the institution of Civil Engineers he stated* that the discharge of the river for the ten years during which records had been taken varied from 22,416 millions of cubic feet representing 32 inches over the whole drainage area in 1894 (a year of exceptional drought), and 54,640 millions of cubic feet or 78 inches in 1891, the average being a little over 50 inches. In 1896 the run-off was about 60 inches. Recent experience shows that the ground can absorb a good deal of rain as there is very little run-off in the hot weather and for some time after the south-west monsoon sets in, but once the country gets well saturated, conditions are favourable to the discharge of a large proportion of the rainfall. There is nothing to indicate that dangerous floods may occur in the south-west monsoon. The heavy rains which produced excessive floods in other rivers last year caused the lake to rise to only 6½ feet on the escape. It is in the north-east monsoon that the heaviest floods occur when cyclones coming from the east or north-east may strike the hills along the whole length of the basin and passing over cause heavy rain over the whole area at the same time. All conditions—form, slope and previous saturation—are then highly favourable to an excessive

* See Proceedings, Volume CXXVIII.

flood discharge. The cyclone of 1869 caused great destruction in the Madura and Tinnevelly districts, and at Periyár seems to have lasted over one and part of two days. If the rainfall was, as stated by Mr. Pears, 28 inches, and it be assumed that this represented the fall from first to last, it is highly probable that the average for the whole area during the 24 hours of greatest intensity was not less than 12 inches and the run-off of 8 inches which is the total of the discharges in table No. IV of the Blue-book seems not by any means incredible. The lake levels have been recalculated for the discharges given in the table with the result that at the end of the period of 25 hours the level would be half a foot over the parapets of the main dam and still rising though slowly. The maximum rate of discharge of the river is given at 531 millions of cubic feet in an hour, or 147,500 cubic feet per second. This gives a coefficient in Dicken's formula, which seems more suitable than Ryves' for small or compact areas of 2,020.

5. Appended to this report are the calculations of flood discharge from the catchment basin of the Tansa lake in July 1894, from levels recorded in the Proceedings * of the Institute of Civil Engineers. The result arrived at is a coefficient of 2,777 in Dicken's formula, the discharge being taken for a period of $2\frac{1}{2}$ hours. If the levels had been more frequently registered, no doubt a higher rate of discharge would have been found. The record does not go far enough to allow the run-off in 24 hours to be calculated. For *12* hours it is found to have been 9·19 inches. It is to be noted that the area of the Tansa lake at maximum level was $11\frac{1}{4}$ per cent. of the catchment, while the area of the Periyár lake would be only 4 per cent.

* Volume CXIX.

6. There was occasion not long ago to calculate the discharge of the Varahanadi at Periakulam, Madura district. It was found to give a coefficient of 2,137 in Ryves' and 1,543 in Dicken's formula. The catchment area is 50 square miles, of which about half is on the slopes of the hills.

7. There is, however, no reliable formula connecting discharge and areas, nor is it likely there ever will be one, the conditions of catchment areas being infinitely various and observations of areas of the same extent and pretty similar conditions are the only safe guide. It has not been possible to obtain any such observations as would help much in settling the Periyár question. The area nearest in extent for which the discharge has been calculated is that above the Cannadian anicut on the Tambraparni a few miles from the hills. The observations of the flood of 29th—31st December 1895 are not sufficiently complete, but an attempt at calculation has been made with the result that the coefficient of maximum discharge works out to 1,272 and the run-off to 7·3 inches in 24 hours. The rainfall at the northern edge of the basin was not very heavy, being only 8 inches during the three days. There was, however, very heavy rain on the hills to the south and not very far away, the return showing $36\frac{1}{2}$ inches for the week ending 31st December.

8. The general inference from all the information which has been obtained is that even if the flood of 1869 at the Periyár was over-estimated, a flood of the magnitude recorded in the Blue-book is not only possible but probable, and in taking it as a maximum for purposes of calculation a margin should be allowed for error. With the same quantity of water to deal with, the lake would rise higher than estimated if the river discharge increased regularly instead of dropping as shown between 12th and 17th hours.

9. It remains to consider what should be done. If water is allowed to rise much above the dam it may cause injurious strains. With 2 feet over the parapets the line of pressure for 20 to 30 feet from the crest (calculations have not been made for lower sections) would fall about one-fourth of the width from the outer edge. This would produce tension in the face with, possibly, a serious result. The absence of such tension is now universally regarded as a necessary condition of safety. There are two ways of improving the means of discharge. One is that suggested by the Inspector-General to lower the level of the escape. No estimate of the cost of this has been made, but it would amount to a good deal and it is doubtful whether the great loss of water which would occur after every fresh before the falling shutters could be raised would not make it preferable to adopt the other plan of removing the

parapets of the main dam and letting water go over the crest in extraordinary floods. Such floods would occur not more than once in ten years and last a very short time. Water passing over the middle part of the dam would fall into 20 or 30 feet of water, and if further security were necessary, a masonry apron could be laid in the old river bed. As the whole of the dam is built on rock, it is believed there can be no danger in allowing a moderate depth of water to pass over. It is intended to inspect the dam as soon as the rains are over and have estimates made either for lowering the escape or replacing the parapets by a railing whichever, on the whole, seems the better.

10. The Inspector-General remained a very short time in Madras on his return from the Periyár, and it was not known that his information was incomplete, else more would have been given. The following figures will, perhaps, give all he requires. The area of tunnel averages about 95 square feet. The fall in the bed of the tunnel is 75 feet, the discharge with lake nearly full was estimated roughly at 1,134 cubic feet per second; 8 feet depth on sill at head will fill the tunnel. With the additional 29 feet head when the lake is full, the total fall would be 104 feet. The extreme rates of discharge are theoretically proportioned to $\sqrt{104}$ and $\sqrt{75}$, a variation of 15 per cent., but the actual seems to be rather less.

(Signed) W. HUGHES,
Chief Engineer for Irrigation.

MADRAS,
2nd October 1897.

ENCLOSURE.

Periyár Lake.

CALCULATIONS of water level for flood similar to that of November 1869, discharges of which are given in the Blue-book, Table IV.

Let A = average area of lake during time T.
" D = river discharge, cubic feet per second.
" h = depth on escape.
" $c\,L\,h^{\frac{3}{2}}$ = discharge over escape.
" c = 2·5 as escape is a bye-wash with rough bed and width about 200 feet front to rear.
" t = unit of time.
" L = length of escape = 434 feet.

The increase in the contents of the lake is equal to river discharge less what is passed over escape. Whence the general equation is—

$$A\,dh = D\,dt - cLh^{\frac{3}{2}}\,dt.$$

Let $h = z^2$, Whence $h^{\frac{3}{2}} = z^3$ and $dh = 2z\,dz$.

$$\text{Then } dt = \frac{A \times 2z\,dz}{D - cLz^3} = \frac{2\,A z\,dz}{D\left(1 - \frac{cL}{D}\,z^3\right)}$$

$$= \frac{2Az\,dz}{D}\left\{1 + \frac{cL}{D}\,z^3 + \frac{c^2L^2z^6}{D^2} + \&c.\right\}$$

$$= \frac{A}{D}\left\{2z\,dz + \frac{2cL}{D}\,z^4\,dz + \frac{2c^2L^2z^7}{D^2}\,dz + \&c.\right\}$$

Integrating between limits $z = \sqrt{h_2}$ and $z = \sqrt{h_1}$.

$$T = \frac{A}{D}(z_2^2 - z_1^2) + \tfrac{2}{5}\,cL\,\frac{A}{D^2}(z_2^5 - z_1^5) + \tfrac{1}{4}\,\frac{c^2L^2A}{D^3}(z_2^8 - z_1^8)$$

Taking h_2 = depth on escape at end of time T.
h_1 = " " at beginning of time T.
and substituting in the above equation—

$$T = \frac{A}{D}(h_2 - h_1) + \tfrac{2}{5}\,\frac{cLA}{D^2}(h_2^{\frac{5}{2}} - h_1^{\frac{5}{2}}) + \tfrac{1}{4}\,\frac{c^2L^2A}{D^3}\,(h_2^4 - h_1^4)$$

If discharges are taken in cubic feet per hour, let D_m = discharge = 3,600 D. Entering this and the values of constants the equation becomes—

$$T\text{ (hours)} = \frac{A}{D_m}(h_2 - h_1) + \frac{1{,}562{,}400 \times A}{D_m^2}(h_2^{\frac{5}{2}} - h_1^{\frac{5}{2}}) + \frac{1{,}059{,}502{,}500\,A}{D_m^3}(h_2^4 - h_1^4)$$

The third term on the right hand side of the equation may be neglected when D_m is high or $(h_2 - h_1)$ small.

It is unnecessary to give all the calculations which are very long. The following table shows the result:—

Period in hours. From	Period in hours. To	Area of lake, square feet.	Discharge of river, cubic feet per hour.	Depth on escape. Beginning of period.	Depth on escape. End of period.
0	6½	285,000,000	130,000,000	0	2·8
6½	7½	292,000,000	209,000,000	2·8	3·4
7½	8½	295,000,000	243,000,000	3·4	4·0
8½	9½	297,000,000	272,000,000	4·0	4·8
9½	10½	300,000,000	294,000,000	4·8	5·6
10½	11½	304,000,000	291,000,000	5·6	6·4
11½	12½	307,000,000	251,000,000	6·4	7·0
12½	13½	309,000,000	200,000,000	7·0	7·5
13½	14½	311,000,000	153,000,000	7·5	7·8
14½	15½	312,000,000	118,000,000	7·8	7·9
15½	16½	312,000,000	105,000,000	7·9	8·0
16½	17½	312,000,000	118,000,000	8·0	8·1
17½	21	317,000,000	315,000,000	8·1	10·6
21	22	325,000,000	531,000,000	10·6	12·0
22	23	332,000,000	516,000,000	12·0	13·2
23	24	337,000,000	457,000,000	13·2	14·2
24	25	341,000,000	309,000,000	14·2	14·5

or ·5 feet over parapets of main dam. The discharge over the dam with this depth is neglected.

Tansa Lake.

1894, 19th July, 6-0 P.M., R.L. 405·16
" 20th " 6-0 A.M., " 406·20
" " " 8-30 A.M., " 408·15
" " " 9-30 A.M., " 408.00
" " " 12-0 noon, " 407·70
" " " 6-0 P.M., " 407·30

Waste weir level 405;— length 1,650.
Dam level 408 — length 6,150.
Drainage area, 52 square miles.

Rainfall at dam—
19th July 6 P.M. to 20th July 6 A.M. } 6·25 inches.
20th July 6 A.M. to 20th July 6 P.M. } 5·63 inches.

} Rainfall at site cannot be regarded as an index of the general rainfall on the catchment area.

Area of lake 25 feet below F.S.L. = 91·0 millions square feet.
" at " = 157·0 " "
Assuming the area to increase above F.S.L. in the same proportion—
Area at 406·2 = 160·17 millions square feet.
" 407·3 = 163·07 " "
" 408·15 = 165·32 " "
Mr. Clerke takes a coefficient of discharge for escape = ·7, but this appears very high.
The assumed coefficient in the following calculations is ·6:—

Discharge at level 405·16 = 3·2 × 1,650 × ·16 × ·4 = 338 cubic feet per second.
" 406·20 = 3·2 × 1,650 × 1·2 × 1·1 = 6,970.
Average discharge for 12 hours 3,654
Total discharge 3,654 × 12 × 3,600 = 157,852,800
Discharge at level 408·15 = 5,280 × 3·15 × 1·775 = 29,522
Over dam = 500
30,022

Average rate of discharge $\frac{30,022 + 6,970}{2}$ = 18,496 c. ft. per sec.

Discharge 6 A.M. to 8-30 A.M. = 18,496 × 3,600 × 2½ = 166,464,000.
Discharge at level 408 = 5,280 × 3 × 1·73 = 27,403.
Discharge 8-30 A.M. to 9-30 A.M. = 28,712 × 3,600 = 103,363,200.
Discharge at level 407·70 = 5,280 × 2·70 × 1·64 = 23,380.
Discharge 9-30 A.M. to 12-0 = $\frac{27,403 + 23,380}{2}$ × 2½ × 3,600 = 228,523,000.
Discharge at level 407·30 = 5,280 × 2·3 × 1·51 = 18,337.
Discharge 12 noon to 6 P.M. = $\frac{23,380 + 18,337}{2}$ × 6 × 3,600 = 450,543,600.

Discharge 12 hours, 6 A.M. to 6 P.M., on 20th = 166,464,000
103,363,200
228,523,000
450,543,600
Add contents of lake between 406·2 and 407·3 ... 161,620,000
1,110,513,800

Area of catchment = 52 × 27,878,400 = 1,449,676,800 square feet.
Run off = $\frac{1,110,513,800}{1,449,676,800}$ × 12 = 9·19 inches in 12 hours.
Maximum rate of discharge 6 A.M. to 8-30 = 166,464,000
Contents of lake between levels 406·2 and 408·15
= $\frac{160·17 + 165·32}{2}$ × 1·95 = 317,352,800
In 2½ hours 483,816,800
In 1 hour ... ... 193,526,720 c. ft.
In 1 second 53,757
Dicken's formula A = 52. $A^{\frac{2}{3}}$ = 19·36. C = $\frac{53,757}{19·36}$ = 2,777

ORDER—No. 992 I., dated 10th November 1897.

The submission of the estimates referred to in paragraph 9 of the foregoing note by the Chief Engineer for Irrigation will be awaited.

2. Ordered that the following letter be sent.

[Here enter No. 993 I., dated 10th November 1897.]

(True Extract.)

Under Secretary to Government,
Irrigation Branch.

To the Chief Engineer for Irrigation.
" the Superintending Engineer, VI Circle.
" other Superintending Engineers.
" the Examiner, Public Works Accounts.
" the Revenue Department.

Exd. T. K. Narayana Aiyangar.