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MADRAS RECORD OFFICE.

Government of Madras.

DEPARTMENT.

Public works.

G.O. No. *1248*

Press
Mis.

428-429.

Dated *24-4-1868.*

Not to be folded or roughly handled

No. 428. Read the following letter from the Consulting Engineer for Irrigation and Canal Company, to the Secretary to Government, Department Public Works, dated Madras, 17th March 1868, No. 152 :—

Enclosures.—Four Plans and a Tracing from Atlas sheet No. 42.

1. The information regarding reservoir projects under investigation by the officers of the Madras Irrigation and Canal Company, already laid before Government, is contained in the papers printed in the Proceedings of Government as per margin. I have just paid another visit to the part of the Mysore territory in which further investigations for reservoirs on the Budra, Toonga, and Choardy have been recently in progress, and I have the honor to subjoin a few additional particulars, which may be considered of interest, as showing the progress made, and the further information which will be needed.

2. For this proposed reservoir the Executive Engineer, Mr. Gordon, has prepared a design for a dam at the point where the river Budra passes through a narrow opening in the hills, near the village of Luckawully, and the surplus water is intended to be passed at a detached saddle, about half a mile to the north. The general features of the arrangement are shown on the accompanying plan, and it will be seen that the dam consists of a wall of masonry and concrete 174 feet high, with a base of 124 feet, and a top width of 5 feet, the batter in front being $14\frac{1}{2}$ feet, and that in rear $104\frac{1}{2}$ feet. The depth of water, when up to the crest of the waste weir, will be 160 feet, and this depth would be liable to increase to 170 feet should a maximum fresh occur at a time when the tank may be full. Therefore in calculating the pressure to be resisted, 170 feet have been taken as the depth. The masonry dam will offer a resistance equal to about twice the force which would be generated by that depth of water, and, in order to increase the stability of the dam, the lower part is shown as carried up vertically for a height of 48 feet, and upon the rear portion a series of retaining walls will provide for the loading of the rear slope with earth and stones, thus raising the ratio of resistance to between 2.6 and 2.7 to 1. The wall will be composed of stone masonry, brick-work, and concrete, and the weight of a cubic foot has been taken as, on the average, 120 lbs., the weight of a cubic foot of the earth and stone loading has been assumed to be 100 lbs.

3. The waste weir has been designed, but, on visiting the site, it appeared to me that a more detailed examination would be necessary, in order to ascertain the exact position, extent, and quality of the rock which there, on the ridge line, appears above the surface, and the Executive Engineer at once directed the requisite clearance to be made, and trenches to be cut, at intervals of about 100 feet, transversely to the direction of the proposed weir, so that the best position for it as well as the most suitable arrangements for receiving the overfall might be ascertained. The lowest point of the saddle is at 125½ feet, 160 feet being full tank level. At the low central portion, even should the rock be as well adapted to receive the overfall as has been supposed, a second line of wall will be needed,

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Luckawully site.

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and this has been provided for. Mr. Gordon estimates the maximum discharge of the river at eight millions of cubic yards per hour, but the weir is intended to provide for a discharge of ten millions, with a depth of 10 feet on the crest, and the length of the latter necessary is therefore, in round numbers, 700 feet.

4. The sluices proposed are two sets at the south end of the main dam, each to be capable of discharging 500,000 cubic yards an hour, the silt of the lower set being at 65 feet, and of the upper set 110 feet above zero. A smaller set is intended to be placed in the waste weir.

5. For passing summer water and low freshes, during the time of construction of the main dam, five arches are shown in the design; that in the centre has a span of 60 feet, rise 15 feet, thickness of arch 4 feet; the other four arches are of 30 feet span, and are semi-circular with a thickness of 3 feet. The piers are 45 feet thick, and are 30 feet high to the springing. Supposing this arrangement to be adopted, it would be advisable to make the central arch semi-circular, and to increase considerably, perhaps to double, the thickness of all the arches. These arches, after serving their primary purpose during the construction of the dam, may either be blocked up entirely, or sluices may be inserted in them for discharging the lower portion of the tank water, in which case a sluice platform, at about 90 feet above zero, would be required. The dam itself would need considerable modification, to allow of these deep sluices being worked from the road-way at top.

6. As before mentioned, the bed of the river, at the gap where the dam is intended to be built, is composed of stratified rock, having a nearly vertical dip. This rock evidently forms the axis of the hills, and it reappears on the surface at the waste weir saddle, and presents the same appearance. It varies in character considerably, some of the strata being extremely hard, and others much less so.

* Since ascertained to be Transition Slate, Cellular Trap, Stratified Quartzite. These specimens, obtained from the river bed, have been given to me by Mr. Gordon, and I will ascertain* to what formation they belong.

7. The waste water, after passing the weir, is to be conducted back to the river by a channel, on the further side of which a training bank is to be thrown up to guide the water until the channel shall have assumed a permanent form. The greater part of the soil over the area between the channel and the hill will be required for the rear slope of the main dam, and for the embankments at the two ends, as also for brick-making. Several trial pits have been sunk, and excellent clay requirements of the works as designed.

8. The rock in the bed of the river is for the most part not adapted for any masonry other than random rubble, but at about five miles north of Luckawully an excellent stone for coursed masonry is obtainable. This stone† which weighs about 170 lbs. to the cubic foot, and is very compact and close-grained, will, I think, be found well adapted not only for wall work, but for the linings of the sluices, &c. There is also very good granite to be had in any quantity from Teerthully on the Toonga, distant 20 miles, and probably from a nearer point.

9. The regular survey of the area within the contour has not as yet been commenced, the survey parties having been engaged on the other sites, where the extent of cultivated land liable to submergence is very much greater than in this case, in which nearly all the area is covered with dense jungle. This being the case the actual area and capacity have yet to be more accurately determined than can be done from the data already obtained. The estimated area is square miles 20, and the capacity 1,225 millions of cubic yards.

10. The information also regarding the discharge of the river is still far from complete. One year's observations have been taken since the particulars given in the papers printed in Proceedings of the Madras Government of the 23rd July 1866 were obtained, but the results have not yet been calculated. It will be advisable to register, very carefully, the freshes of the season which will shortly commence, and it is necessary also that the data on which the discharge of a maximum fresh may have been estimated should be very clearly explained, otherwise it will be impracticable to judge whether the dimensions of the waste weir are sufficient. It may be noticed that a discharge of eight millions of cubic yards in the twenty-four hours is equivalent to a rain-fall drainage of three inches, which does not seem to be very large, as the maximum from a basin of 760 square miles. However, though this may represent a very much heavier rain-fall, seeing that the greater part of the area is covered with deep vegetable soil, and though the proposed waste works and sluices will discharge about eleven millions instead of eight millions, the actual maximum discharge should be ascertained as accurately as may be possible, by finding out the level reached by the freshes at several points, and connecting this information with cross and longitudinal sections of the river. Works of such magnitude, as the reservoirs contemplated by the Company, require that every possible precaution should be taken, and this can only be done by obtaining full information on all points on which the arrangements, by which security is to be ensured, must be based, for an accident would not only lead to great pecuniary loss, but would devastate a vast extent of country, and occasion a great sacrifice of life.

11. It has been noticed that the maximum water level with 10 feet going over the waste weir will be 170 feet, and that the level of the road-way over the main dam is 174. The margin will be increased by massive parapets 6 feet high, which will bring the level of the dam up to 180 feet above zero.

12. Estimates for the reservoir have been prepared, and they amount to Rupees 30,97,110, the works and their cost being:—

Main dam	...	...	...	Rupees 27,16,710
Channels from sluices	...	...	...	" 47,100
Waste weir	...	...	...	" 1,93,900
Sluices in do.	...	...	...	" 36,000
Waste water channel	...	...	...	" 1,03,400
				30,97,110

13. The quantities and descriptions of work in the main dam, with the rates allowed, will afford data for judging of the sufficiency of the estimates, and they are accordingly given in detail below:—

*Proceedings of the Madras Government, Public Works Department,
24th April 1868.*

	Quantities.	Unit.	Description of work.	Rate.			Amount including contingencies.
	2,252	C. yd.	Rock excavation in river	RS.	A.	P.	RS.
	3,759	"	Do. for wings, &c...	2	0	0	11,160
Cubic yards 1,72,914 at Rupees 8-11-6	29,119	"	Earth excavation	1	8	0	
	46,68,694	C. ft.	Coursed rubble masonry	0	3	6	7,000
	15,729	C. yd.	Rough rubble masonry	0	5	2	16,58,300
Cubic yards 34,941 at Rupees 6-3-0	9,43,398	C. ft.	Brick masonry	4	13	2	83,450
	2,60,270	"	Stone arch work	0	3	8	2,42,400
Cubic yards 9,633 at Rupees 12-3-9	26,414	"	Brick do.	0	8	6	1,52,100
	2,60,079	"	Hammer dressed masonry	0	4	6	8,170
	11,169	"	Cut-stone masonry (black stone)	0	7	3	1,29,630
	8,030½	"	Do. (granite)	1	2	6	
	1,758	"	Beamstones, &c	1	10	6	32,710
	11,104	"	Coping string	2	0	0	
	4,041	"	courses, &c.	0	7	0	7,010
	50,302	C. yd.	Concrete filling	0	6	0	
	81,420	"	Earth and rubble filling	3	0	0	1,66,000
	2,80,000	"	Embankment, west end of dam	0	7	0	39,180
	28,000	"	Do.	0	2	0	
	89,469	"	Do. selected earth for front...	0	1	3	
	1,66,244	"	Do. do. for rear...	0	8	0	1,68,300
	9,481½	"	Stone pitching	0	5	0	
	454½	"	Backing to do.	2	0	0	
	1,130	Sqrs.	Pointing brick-work with cement	0	6	0	
				10	0	0	11,300
							27,16,710

The most important items in this estimate are the
Brick masonry.
Hammer dressed masonry.
Earthwork in embankment.

The rate allowed for the first is Rupees 8-11-6 a cubic yard, and, even supposing that the whole of the material has to be brought* five or six miles, I think the rate would prove sufficient. The stone intended to be employed is found and has been used in many parts of the country, and there is every probability of its being found, therefore, in sufficient abundance. It is the same as that used for the new sluice at the Masoor tank, and which I at first supposed to be a description of limestone, but Mr. Gordon tells me that it does not contain any lime. I have brought a specimen with me, and its composition and character will be ascertained.* For bricks excellent clay is available in large quantities on the north side of the river, within half a mile of the site for the dam. Wood to burn bricks is to be had in any quantities

* See paragraph 8 above.

* Quartzite or something between Whinstone and Trap.

*Proceedings of the Madras Government, Public Works Department,
24th April 1868.*

close at hand, so that Rupees 6-3-0 a cubic yard should suffice for brick masonry. The same stone would be used for the hammer-dressed as for the coursed rubble masonry, and the additional rate, Rupees 3-8-3 a cubic yard, for the dressing appears to be ample. The rate, two annas a cubic yard, for a large proportion of the earthwork in the west embankment is, I think, too low. Probably it will be obtainable most easily from the plain north-east of the dam, and the average lead could hardly average less than 200 yards, seeing that an area of 265 yards square, cut down to a depth of 4 yards, would be necessary to supply the 2,80,000 cubic yards required; soil could be obtained from the hill side, but there the roots of the jungle would interfere greatly with extensive excavations, even were the trees all cleared away. I am therefore inclined to think that the rate for this work should be doubled, which would add 35,000 Rupees or, with contingencies, say 38,890 Rupees to the estimate, thus making the total Rupees 31,36,000.

14. The probable value of the reservoir, supposing this estimate to be correct,

and assuming the capacity to approximate to 1,225* millions of cubic yards may be stated as follows:—To the

amount of the estimate must be added charges for permanent establishment, Home and Indian Agencies, &c., which, in accordance with the facts of the Kurnool works, may be taken at somewhat under fifty per cent. The total ultimate cost of the reservoir would then be 45 lacs, and the quantity stored for one rupee would be 272½ cubic yards. It may, looking to the character of the river, be considered that the reservoir will be full at the time when Toombudra freshes begin to run low and require supplementing, and also that, on the average, the river supply will

compensate for evaporation† from the surface of the reservoir during the time its supply is being utilized. If then

10,000 cubic yards be taken as the quantity required to be stored to supply one acre of irrigation, the reservoir will, if considered only as an irrigation work, be capable of irrigating 1,22,500 acres, the gross revenue from which, at 6 Rupees an acre, would be Rupees 7,35,000, or 16 per cent. on the outlay. Such being the case, there would be a considerable margin available either for extra cost of works or for the absence of a full utilization of the water. Thus, supposing the works to cost even 60 lacs, and the acreage irrigated not to exceed 80,000 acres, the gross return would still be as much as eight per cent. The figures above given may be liable to considerable modification when the information required regarding the capacity of the reservoir, the maximum and total yearly discharge of the river, &c., is obtained; but they tend to show that, comparatively unfavorable as is the result of the investigations thus far in regard of the quantity of water likely to be stored for each rupee of expenditure, there is every probability of the construction of the Luckawully reservoir proving to be financially desirable.

15. With regard to Mr. Gordon's design, the only point in connection with the main dam which it seems necessary here to notice is the arrangement of the irrigation sluices at the southern end. It will be seen that training walls conduct the water for a distance of about 170 feet, and the water is then to flow into the river. This arrangement, however, is hardly likely to be economically

practicable, unless rock sufficiently hard to stand the wear and tear of the rush of so considerable a body of water should be found with its surface not much below the level of the sluice cills, and thence sloping to the bed of the river. The existence of rock so situated has not been ascertained by sinking shafts down to it; and as, therefore, it is not actually known that rock exists at a level much above the river bed, it is clear that sluices so circumstanced may need a succession of falls below them, and this necessity might make a modification of the arrangements advisable.

16. **TOONGA SITE.**—The investigations in connection with the proposed reservoir on this river are making good progress, but it is not expected that the field work will be finished before the close of next working season, that is, in May 1869; and it will take some months after that date to complete the designs and estimates.

17. The work now going on is the determination of the contour for a depth of 150 feet of water at the Baghully (Bagoli) site, together with that of a ten feet higher level, so as to show the land liable to occasional submergence up to the maximum depth dischargeable at a waste weir. These contours have been determined for a great part of the length on the north side of the river, and some parts of the survey have been checked, and the cross sections are being run. On the south side of the river no new work has been done this season, and what is known of the probable reach of the tank on that side is dependent upon former approximate surveys and levels.

18. So far as the calculations hitherto made can be depended upon, a dam at Baghully, with a depth of 150 feet of water, would form a tank having an area of between 90 and 100 square miles, with a capacity of more than 3,000 millions of cubic yards. It has been ascertained that the 150 feet level would cut the river bed above Teermootoor, *i. e.*, close to the south end of the part of the river shown on Atlas sheet No. 42, or the length of the tank along the river would be about 27 miles.

19. A detached saddle, about one mile north of the Baghully dam site, has been examined, with a view to the construction of a waste weir there. It is the saddle at which the road from Shimoga to Teerthully crosses the range of hill; its level is 133, which is so far suitable, but there is no appearance of rock either at the road or anywhere on the hill between this point and the end of the proposed dam, and the trial pits sunk show nothing harder than laterite gravel. The waste weir must be capable of discharging at least ten millions of cubic yards per hour, and in the absence of rock it is evident that the letting down of such a great quantity of water a depth of 150 feet would cost a very large sum. A detached weir indeed has no advantages to recommend it in cases in which the main dam is intended to be founded on hard rock, unless there be equally good rock at a level above that in the bed of the river at the weir site. Mr. Gordon himself appears to consider that the road-way saddle is practically unadapted for a surplus work, as in the only design as yet sketched out, and that roughly, for a dam at Baghully, he has arranged for the surplus to go over the dam, the falls being divided into two of 46 feet, one of 32½, and one of 25½ feet. I do not doubt the practicability of such an arrangement, for its safety can be ensured by receiving the over-fall on a proper

depth and volume of water, but it will not be advisable to try this plan on such a large scale, at least unless it be ultimately found that no better is available.

20. There does not appear to be a probability of finding another saddle in connection with the Baghully site, but two miles lower down the river, on the north side of what is called the Mudaba site, there is a saddle, which has not yet been examined, and at which it is probable that rock will be found, as the axis of the hill immediately south of the saddle, and on which the north end of a dam would abut, shows rock on the surface similar to that in the bed of the river, of which indeed it is the prolongation.

21. A dam across this part of the Toonga would form such a large reservoir, at so reasonable a proportionate outlay, that it will be advisable to ascertain exhaustively what natural facilities for its construction exist. Should, however, it be found impracticable to obtain a suitable site for a detached weir near this part of the river, there is another site for a dam some miles higher up, which will probably do for a reservoir of large, though not of such large, dimensions, as could be obtained by making a dam at one of the lower sites. This place is at the end of the hill running north north-west from Mailagapett, a village on the south side of the river; and the site would be just where longitude $75^{\circ} 20'$ intersects the river. The hills on the north side are not as shown in the printed map, as they come much near to the river, and the present 150 feet contour lines on the two sides are not more than 2,500 feet apart. A little south of Mailagapett also there is a saddle, which has not been examined, but on the two sides of which a contour has been run, which shows that there would be no great length (about 1,500 feet) of cutting to get down to the 150 feet level, and as that is equivalent to about 100 feet depth at the river, and as with a dam here that depth would be increased, it is possible that the saddle would be found suitable in all respects for a waste weir if the rock which is apparent on the hills near the river be found to run through, and to be at a moderate distance below the surface at the saddle. It will be seen also that the run of surplus water from this saddle to the river would be very short and direct, though the saddle is nearly three miles from the main dam site.

22. One year's observations of the discharge of the river have been taken, but not calculated out, since the discharges given in the Government Order as per margin* were obtained. It is

* No. 2,322, 23rd July 1866.

intended to register the freshes this year, and probably another season's (1869) floods in addition will have been observed before the project will be fully matured.

23. *The Masoor Tank restoration.*—The project for restoring this tank will be ready in a few months. The contour has been completed, and is being worked on the ground; the cross sections have been nearly completed, and the surveys of the cultivated lands are getting on well. It is expected that the whole of the field work will be finished by the end of the present working season, or about the 15th of May.

24. Regarding the discharge of the Choardy, the Executive Engineer has been unable to furnish me with any additional information; but measures have been taken for the registration of the freshes of the next monsoon, and longitudinal and cross sections of the river near Shikarpore have been prepared. The new waste weir, constructed by the Bombay Department of Public Works, will also afford a

separate means of observation, and from the two sets of observations it is expected that the discharge of the river during this season will be tolerably well ascertained. Besides this, Mr. Gordon will be able to compare the rain-fall and discharge of this river with those of the Toonga and Budra, and thus an approximate estimate may be formed of the relation existing between the quantity of water passing down in this year with a given rain-fall, and that discharged with any other, or with an average rain-fall. How far the year 1867, the discharge of the Choardy in which is given in the papers printed in Proceedings of the Madras Government of the 2nd December last, No. 3,745, approximated to an average one, is not as yet known, but it is there shown that the maximum discharge per second was 2,419 cubic feet, on the 20th July. This corresponds to a rain-fall drainage of one-sixth of an inch from the whole basin,*

* Square miles 540. On the other hand, from flood marks Mr. Gordon estimates the maximum discharge at a little less than 15,000 cubic feet per second, and this, which is equivalent to a rain-fall drainage of $1\frac{1}{2}$ inches, does not appear to be excessive. There appears to be no doubt whatever that the tank, as originally constructed, did fill. Mr. Gordon thinks that there is evidence to show that at the time the breach in the west bund, which ruined the tank, occurred, some water went over the main bund, and the Superintendent of the Nuggur Division has traced among the records claims for remission on account of the submergence of lands beyond the ordinary water spread of the old tank, which corresponds very closely with that of the proposed restoration. The year 1867 was an unfavorable one in the Mysore country generally, and it may be, as Mr. Gordon suggests, that when the rain-fall is much under the average, a large proportion of the drainage is stopped by small tanks on the several feeders, while on the contrary, in a better monsoon, the greater part of the difference finds its way to the main river. However further evidence of the extent of the supply is a matter of great importance, and should be obtained, as far as possible, by direct observation, and be supplemented by deductions from rain-fall registers, and by such information as may be obtainable from the Revenue records of the part of the country in the neighbourhood of the tank.

25. The plotting of the contour had not been completed when I was at Shikarpore, and the exact area of the water-spread at full tank level (90 feet), and with five feet of water (the maximum intended) going over the waste weir, had not, therefore, been ascertained, but from approximation from an inferior contour, the full tank area is estimated at 40 square miles. The capacity is similarly expected to be 1,400 millions of cubic yards, and this will be determined as soon as the cross sections shall have been completed.

26. The Executive Engineer has estimated for the restoration of the tank on two different designs.

Vide enclosed Plan No. II.

First.—By a dam across the present surplus channel above the fall, at the site of the Bombay Department of Public Works new waste weir, with a waste weir at the present east bund of the old tank.

Second.—By a dam and weir combined across the present surplus channel.

The designs were worked out in the order above given. The general character of the first dam will be seen from its cross section, which is given in plan No. III. It was intended to have a lower and an upper set of sluices for passing irrigation water; the water from the upper set being allowed to drop through a modified arrangement of the grated fall used in the North-West Provinces. For the surplus work at the east bund two arrangements were planned. The fall to be overcome between the crest of the waste weir and the bed of the Choardy, near Soolcotta, would be about 120 feet; and, in addition to the over-fall at the waste weir itself, six masonry falls were planned. The length of the crest of the waste weir was to be 370 feet, and the greatest depth of water passing over it was to be 5 feet. There is a natural line of drainage, in the shape of a small nullah, running in the direction which the surplus water would take if discharged at this point, and the distance from the weir to the Choardy would be 2,600 yards. Such a weir would be capable of discharging 1,992,820 cubic yards per hour, or 14,946 cubic feet per second. The cost of surplus works so arranged would be Rs. 6,04,660. The alternative arrangement, while retaining the same design for the weir, omitted the masonry falls in the surplus channel, and contemplated allowing the water to cut down until a sufficiently hard substratum might be reached to prevent further action. The estimated cost of this plan is Rupees 3,67,970. No borings have been made on the line of the channel to ascertain what would probably be its ultimate level at various points, and it is clear that it would be necessary to ascertain this with considerable accuracy, in order that the retrogression of levels near the weir might be effectually guarded against. The ultimate expense of either of these systems would be very problematical. The maintenance of seven weirs in the first case would, in the absence of rock on which to found them, necessarily entail a considerable expenditure yearly, even if the estimate proved to be approximately correct with regard to the first cost of making them efficient. The second plan would, even were the result of borings altogether satisfactory, certainly require much additional expenditure, above the first cost of the weir itself, for rendering its tail secure, and for preventing the deepening of the bed up to such a distance below as would ensure freedom from leakage through the sub-soil on which the present bund stands. Mr. Gordon thinks that there is rock between the hills connected by that bund, and if so, it may be of such an extent and character as to make the construction of a weir here practicable at a moderate expense, but the surplus water could not be allowed to cut its own channel below the weir unless it were first clearly ascertained that the rock under and below the weir would not be liable to injury either by undermining or by the effects of the over-fall, even were the channel lower down to cut away to the greatest depth which borings might show to be possible. The cost of the masonry dam, in connection with either

Plan No. II.

Plan III.

of the above waste weirs, would be Rupees 8,47,550. The proposed expenditure on the old main bund is Rupees 91,600, so that the cost of the project on the first plan would be Rupees 15,43,810, and on the second plan Rupees 13,07,120.

27. The difficulties attending an arrangement for the discharge of surplus water at the east bund having thus been found to be very considerable, Mr. Gordon

turned his attention to framing a design for a dam at the present surplus channel, which should serve both for retaining the tank water to the necessary level, and for discharging whatever surplus might thereafter be received. The general features of this arrangement are indicated in Plan No. IV, and are as follow :—

At about 190 feet below the point, where the Bombay Irrigation Department have constructed a dam-wall across the surplus channel, is the ledge or reef of rock over which the river falls some 30 feet into a basin in the rocks below. On this reef it is proposed to build a dam-wall having a length of 150 feet, a top width

of 5 feet, and its crest at 14 feet above datum.* In this dam there are to be six sluices 3 feet by 5 feet for the regulation of the discharge when necessary. At a distance of 60 feet above the lower edge of this weir is a second or intermediate dam, having its crest 33 feet above datum, and having in its body seven sluice vents of 4 feet by 9 feet each. The length of the crest of this dam is to be 209 feet, and the maximum depth passing over would be 8.56 feet. The water passing over this dam would fall into a basin with a hard rock bottom, over which there would be a minimum depth of 12 to 14 feet, and a maximum of 24½ feet; 145 feet above the intermediate, will be, according to this design, the main dam, having a width at base of 70 feet, with its crest arranged in two falls, the upper at a level of 87½ feet above datum, with posts 2½ feet high, and the lower at 77½ feet, with a water cushion having a minimum depth of 9 and a maximum of 15 feet. From the second crest the over-fall will be 46 feet to the level of the crest of the second dam, and the minimum depth of water to receive the fall will be 33 feet, and the maximum 41.56 feet.

28. It appears to me that the arrangement just described is altogether preferable to that by which the surplus water would be discharged at the east bund. In either case the water has to be lowered the same depth, viz., the difference between full tank level and the bed of the Choardy; while in the one case there is rock, the quality of which is known, and which has stood the wear and tear of the whole discharge for many years, and in the other there can be at best only untried rock, and it is doubtful whether anything harder than partially decomposed granitic rock would be found at all. The difference of expense, though important, is nevertheless a secondary consideration, it being of the first consequence to obtain a safe design, and, in my opinion, the system of divided falls with water cushions is not only the safer after the completion of the whole works, but it admits of the works during construction being carried on without any serious risk. The third or lowest dam may be built first, and the others can be raised successively, just so fast as circumstances may dictate; and a fresh in excess of the capacity of the sluices might pass over the walls at any stage of their progress without occasioning any damage of consequence. The small dam on the edge of the falls could be completed in a few months, and there need, I think, be no doubt of its stability, as the over-fall will be received into a basin of considerable depth, and the rock there having stood an over-fall of 30 feet for a great number of years, would probably not be affected by the additional height, 14 feet, of the proposed over-fall, to an extent which would be likely to undermine the dam, though it is very possible that the pool may be somewhat deepened. There would be time before damage had become imminent to provide a remedy, and this remedy would be simple and inexpensive, as the most that

would be necessary would be the reduction of the fall within safe limits by the construction of another wall across the pool below the third dam. The security of the intermediate and main dams will depend mainly on the depth of water in the basins below them, and the depths provided by Mr. Gordon appear to be sufficient. By the formula used for the water cushions of vertical falls in the North-

Western Provinces, the depth of the cushion of the greater fall would, for brick-work, be 17.98 feet, while that allowed here with a hard rock bottom, is 33 feet, or perhaps more correctly 35.86. Similarly, below the second

$$\begin{aligned} D &= 1.5 \sqrt{h} \times \sqrt[3]{v d} \\ &= 1.5 \sqrt{43.5} \times \sqrt[3]{6} \\ &= 17.98. \end{aligned}$$

dam the cushion required by the formula would be 12.54 feet, and that proposed is 16.19 feet. I have quoted this formula be-

$$1.5 \sqrt{16.81} \times \sqrt[3]{8.56}.$$

cause it has, I believe, been successfully applied to the falls on some of the canals in the North West, but I do not know on what principle it is based. It perhaps errs in giving too small a depth of cushion for high falls. The extreme example of proportion between cushion and fall, with which I am acquainted, is that of the Rajah fall at Gairsoppa, the height of which is 829 feet, and the depth of the pool 130 feet. I do not know what the maximum depth going over would be, but I think not more than 15 feet, the cube root of which would be nearly 2.5, making the depth of cushion for brick-work, according

$$1.5 \sqrt{829} \times \sqrt[3]{15}.$$

to the formula, 107.95 feet, which is too little by about one-fourth—for stone masonry, to

which rock would more nearly approximate, the depth of cushion allowed by the formula would for the same fall be 71.97 feet, or not much more than half the actual depth at the Rajah fall.

29. A great advantage of this system would be, under the circumstances of the site, that it is not likely that any expensive additions will be needed to supplement the works as originally carried out. The existing rock and the water will, between them, absorb the forces generated, and the artificial dams will be subjected to nothing more than the wear and tear of the body wall of an anicut, which is nearly always inconsiderable.

30. In order, however, to secure the satisfactory action of the water cushions, it is essential that the sluices in the several dams be fully under command, in order that the first and second basins may always be full when any water begins to pass over either the main or intermediate dam. All the sluices should, therefore, be capable of being worked at all times, and this can only be done by placing the gear connected with them on platforms above the maximum level of the water.

31. I should be disposed to omit the posts on the first crest of the main dam, and to put the sluices which will be needed for the discharge of irrigation water at the two ends, where their platforms, which must be above the 95 feet level, will not interfere with the crest of the weir. The lower sluices should be at the base of the dam, for it would be much better to place them here than to give additional low level sluices in the old main bund. A second set might be placed about 30 feet above datum, but as, by means of the intermediate dam, the lower set could always be worked under a head not exceeding 57 feet, and as this gives a pressure of less than two atmospheres, there would be no difficulty whatever in providing suitable gear for regulating openings of 3 to 3½ feet in diameter.

32. The section of the two crests of the main dam might also be altered with advantage, so as to bring the rear edge of the crest to the face of a vertical, or nearly vertical, wall—the width of the water-cushion can be somewhat widened, and the floor should be an invert with a sufficiently high versed sine to prevent the possibility of the displacement of any of its stones.

33. The estimated cost of the dam with water-cushions is Rupees 7,75,462, and probably, after making such modifications as will tend to secure its entire efficiency, the estimate will not exceed nine lacs.

34. The proposed expenditure on the old main bund amounts to Rupees 91,600, and provides for raising the earthworks, where necessary, to 108 feet above datum, and for completing and raising the revetment to the 101 feet level. I think, however, it will not be prudent to rely on this old bund being water-tight. Probably

* About 1,000 feet.

it is so, and its enormous thickness* makes it unlikely that any of those causes, such as rat-holes, faults from settlements, &c., which commonly lead to leakage, can exist to a prejudicial extent. Still all risk should be avoided, and I would, therefore, place a thick wall of puddle behind the revetment. As, however, the interior slope of the bank is every where flat, and in some places as flat, as one in five, the puddle would have to be arranged in steps, and in this manner it could be inserted without necessitating the removal of any very great quantity of the old soil. The minimum depth of rammed soil between the puddle and the revetment might be four feet. The width or thickness of the puddle at base 25 feet and, at the 96 feet level, three feet. The head of the existing sluices will have to be carefully secured.

35. The financial merits of this project cannot of course be accurately ascertained, until present deficiencies of information shall have been remedied. The subjoined estimate, however, will give some idea, and I hope one not too sanguine, of the probable results of the restoration of the tank.

The masonry dam may be taken as likely to cost 9 lacs.

Estimate for old main bund ... 91,600

Add for puddle, say ... 48,000

Do. securing sluice heads ... 10,400

Home and Indian Agency and Permanent Establishments ... 1½ lacs.

... 4½ lacs.

Total ... 15 lacs.

Next, with regard to the probable supply, Lieutenant Smith of the Bombay Department of Public Works estimates the discharge of the Choardy in 1867 at cubic yards 276,454,400. The area of the drainage basin is from 1,500 to 1,600 millions of square yards, so that the above discharge represents a rain-fall drainage of about 6¼ inches during the year. To fill the tank a drainage of, in round numbers, 36 inches is required, and I do not myself think that this will be received except in very favorable years, for the Choardy basin, though well within the south-west monsoon, is very differently circumstanced to the upper parts of the Toonga and Budra. The average supply may perhaps be the equivalent of 20 inches of drainage, or say 800 millions of

cubic yards. The irrigation under the tank and river in the Bombay Presidency in 1866-67 was not very extensive,*

* 180 Acres.

but it appears to be expected that this area will be extended sufficiently to absorb 110 cubic feet per second, and this is stated to be enough for $50 \times 110 = 5,500$ acres of rice throughout the year, which may be put, as regards total quantity of water required, as equivalent to 13,000 acres for a single crop. Allowing 10,000 cubic yards as the storage for one acre, the Bombay Irrigation would absorb 130 millions of cubic yards; 150 millions will, therefore, be taken as the quantity for which the Company would obtain no returns. Evaporation will, as regards this reservoir, be a not unimportant item. The area of the tank, when containing the average supply (800 millions cubic yards) will probably be about 28 square miles. The average area from which evaporation will take place during six months may be assumed to be 16 square miles, or 48 millions of square yards, and at one-fourth of an inch per diem the quantity evaporated in the six months will be, in round numbers, 150 millions of cubic yards.

36. It appears then that the average quantity of stored water which will be available annually for transmission to the Company's canals, under the Toombudra, will be about 500 millions of cubic yards, or enough for 50,000 acres. The gross returns, therefore, at 6 Rupees an acre, would be three lacs or 20 per cent. on the supposed outlay, 15 lacs, required for the carrying out of the project.

37. I have been obliged to calculate the value of the water stored in terms of the area capable of irrigation thereby, this being the readiest and most intelligible way of expressing it; but it is very probable that, should the Company construct these reservoirs, a good deal of the water will not be so utilized, but will be used for maintaining navigation throughout the year on the Kurnool Main Canal, and on any other canals which may hereafter be constructed. I have, however, little doubt that, except for the very short time in each year during which there will be no cultivation going on any where, there will ultimately be but very little water which will not be employed in rendering cultivation secure, as well as for navigation. Fully to develop the Kurnool works somewhere about 600,000 cubic yards an hour for six months need to be provided by storage, and the total quantity would, therefore, be 2,592 millions of cubic yards, or say 2,600 millions. Nothing but experience will afford entirely safe grounds for estimating the value of large reservoirs, but the circumstances of the Company's Kurnool Canal appear to me to offer a particularly favorable opportunity for ascertaining that value, seeing that it requires no elaborate argument to show that a perennial, or nearly continuous, water-supply, with the 2nd crops, and more efficient navigation, therefrom attainable, would not only increase the revenue largely, but reduce the relative cost of maintenance in almost direct proportion to the increase of receipts. It is indeed not improbable that it would be worth while to expend half the cost of the Kurnool Main Canal, which for present purposes may be supposed to be 160 lacs, in the attainment of this object. The Masoor reservoir project is from its comparatively moderate dimensions, and estimated cost, better fitted than any other, which has thus far been brought under notice, for a first experiment, and I hope it will be so brought forward by the Company as to leave no important point, upon which information can be obtained, in doubt.

38. As regards the interest of the Bombay Government in the supply of water from the Choardy, there would seem to be no difficulty in providing, by

Consulting Engineer's Office
Irrigation Canal Company
Madras, 17th March 1868.
Dy. 23

No 152

From,
Captain J. Mulline, R.E.
Engineer for I.C. Co.

Enclosures
5 Plans.

To,
The Secretary to Government
Department of Pub. Works.

Sir,
The information regarding reservoir projects, under investigation by the Officers of the Madras Irrigation and Canal Company, already laid before Government, is contained in the papers printed in the Proceedings of Government as per margin. I have just paid another visit to the part of the Mysore territory in which further investigations for reservoirs on the Budra, Loong and Choardy have been recently in progress, and I have the honor to subjoin a few additional particulars, which may be considered of interest, as shewing the progress made and the further information which will be needed.

P.M. 17th 22nd 19th 23rd July/66.

Enclosures to Plans
and a tracing from
Atlas Sheet 1. 2. 3.

Suchawully site. 2. For this proposed reservoir, the Executive Engineer, Mr. Gordon, has prepared a design for

for a dam at the point where the
Rudra passes through a narrow opening
in the hills near the village of Puckawully
and the surplus water is intended to be
passed at a detached saddle about half
a mile to the North. The general features
of the arrangement are shown on the ac-
companying plan, and it will be seen that
the dam consists of a wall of masonry and
concrete 174 feet high, with a base of 124
feet, and a top width of 5 feet, the batter
in front being $14\frac{1}{2}$ feet and that in rear
 $10\frac{1}{2}$ feet. The depth of water, when up
to the crest of the waste weir, will be 160
feet, and this depth would be liable to in-
crease to 170' should a maximum fresh
occur at a time when the tank may be full.
Therefore, in calculating the pressure to
be resisted, 170 feet have been taken as the
depth. The masonry dam will offer a
resistance equal to about twice the force
which would be generated by that depth of
water, and, in order to increase the stability
of the dam, the lower part is shown as car-
ried up vertically for a height of 48 feet,
and upon the rear portion a series of retain-
ing walls will provide for the loading of
the rear slope with earth.

2.6 and 2.7 to 1. The wall will be
of stone masonry, brickwork, and concrete,
and the weight of a cubic foot has been taken
as, on the average, 120 lbs. the weight of a
cubic foot of the earth and stone loading
has been assumed to be 100 lbs. —

3. The waste weir has been designed, but,
on visiting the site, it appeared to me that
a more detailed examination would be ne-
cessary, in order to ascertain the exact po-
sition, extent, and quality of the rock
which there, on the ridge line, appears
above the surface, and the Executive Engineer
at once directed the requisite clearance to be
made, and trenches to be cut, at intervals
of about 100 feet, transversely to the direction
of the proposed weir, so that the best posi-
tion for it as well as the ^{most} suitable
arrangements for receiving the overfall
might be ascertained. The lowest point
of the saddle is at $123\frac{1}{4}$ feet, 160 feet being
full tank level. At the low central por-
tion, even should the rock be as well
adapted to receive the overfall as has been
supposed, a second line of wall will be need-
ed, and this has been provided for. Mr Gordon
estimates the maximum discharge of the
river at 8 millions of cubic yards per hour,
but the weir is intended to provide for a discharge

of 10 millions, with a depth of 10 feet on the crest, and the length of the latter necessary is therefore, in round numbers, 700 feet.

4. The sluices proposed are two sets at the south end of the main dam, each to be capable of discharging 50,000 cubic yards an hour, the sill of the lower set being at 65 feet, and of the upper set 110 feet above zero. A smaller set is intended to be placed in the waste weir.

5. For passing summer water and low freshes, during the time of construction of the main dam, 5 arches are shown in the design; that in the centre has a span of 60 feet, rise 15 feet, thickness of arch 4 feet; the other 4 arches are of 30 feet span and are semicircular with a thickness of 3 feet. The piers are 45 feet thick, and are 30 feet high to the springing. Supposing this arrangement to be adopted it would be advisable to make the central arch semicircular, and to increase considerably - perhaps to double - the thickness of all the arches. These arches after serving their primary purpose during the construction of the dam, may either be blocked up entirely, or sluices may be inserted in them for discharging the lower portion of the dam.

platform at about 90 feet above zero would be required. The dam itself would need considerable modification to allow of these deep sluices being worked from the roadway at top.

6. As before mentioned the bed of the river, at the gap where the dam is intended to be built, is composed of stratified rock, having a nearly vertical dip. This rock evidently forms the axis of the hill; and it reappears on the surface at the waste weir saddle, and presents the same appearance. It varies in character considerably, some of the strata being extremely hard and others much less so. Three specimens obtained from the river bed, have been given to me by Mr Gordon, and I will ascertain to what formation they belong.

7. The waste water after passing the weir is to be conducted back to the river by a channel, on the further side of which a training bank is to be thrown up to guide the water until the channel shall have assumed a permanent form. The greater part of the soil over the area between the channel and the hill will be required for the rear slope of the main dam, & the embankments at the two ends.

x Since ascertained to
be Transition slate
Cellular traps
Sintered Quartzite

is also for brickmaking. Several trial
pits have been sunk and excellent clay
either for puddling or for brickmaking is
obtainable in sufficient quantities for the
requirements of the works as designed.

8. The rock in the bed of the river is for
the most part not adapted for any masonry
other than random rubble, but at about 5
miles north of Nuskavully an excellent
stone for coarse masonry is obtainable.

This stone which weighs about 170 lbs to the
cubic foot, and is very compact and close grained
well, it thinks, be found well adapted not only for
wall work but for the linings of the sluices ^{There is also very good} to be
had in any quantity from Perthully on
the Coonga, distant 20 miles, and probably
from a nearer point.

* Quartzite or some
thing between whin-
stone and trap

9. The regular survey of the area within
the contour has not as yet been commenced,
the survey parties having been engaged on
the other sites, where the extent of cultivated
land liable to submergence is very much
greater than in this case, in which nearly
all the area is covered with dense jungle.
This being the case the actual area and
capacity have yet to be more accurately
determined than can be done from the data
already obtained. The estimated area is
square miles 20, and the capacity 122.8 millions

10. The information also regarding the
discharge of the river is still far from com-
plete. One year's observations have been
taken since the particulars given in the
papers printed in Proceedings of the Madras
Government of the 23rd July 1866 were ob-
tained, but the results have not yet been
calculated. It will be advisable to register
very carefully the freshes of the season
which will shortly commence, and it is
necessary also that the data on which the
discharge of a maximum fresh may have
been estimated should be very clearly ex-
plained, otherwise it will be impractica-
ble to judge whether the dimensions of
the waste weir are sufficient. It may be
noticed that a discharge of 8 millions of
cubic yards in the 24 hours is equivalent
to a rainfall drainage of 3 inches, which
does not seem to be very large as the max-
imum from a basin of 760 square miles.
However, though this may represent a very
much heavier rainfall, seeing that the
greater part of the area is covered with
deep vegetable soil, and though the pro-
posed waste works and sluices will dis-
charge about 11 millions instead of 8 mil-
lions, the actual maximum discharge
should be ascertained as accurately as may

is possible, by sending out the level reached by the fresher at several points, and connecting this information with cross and longitudinal sections of the river. — Works of such magnitude as the Reservoirs contemplated by the Company require that every possible precaution should be taken, and this can only be done by obtaining full information on all points on which the arrangements by which security is to be ensured, must be based — for an accident would not only lead to great pecuniary loss, but would devastate a vast extent of country, and occasion a great sacrifice of life. —

11. It has been noticed that the maximum water level with 10 feet going over the waste weir will be 170', and that the level of the roadway over the main dam is 174'. — The margin will be increased by massive parapets 6 feet high, which will bring the level of the dam up to 180 feet above zero. —

12. Estimates for the Reservoir have been prepared, and they amount to Rupees 30,97,110, the works and their cost being:

Main dam	Rs. 27,16,710
Channels from sluices	47,100
Waste weir	19,39,000
Sluices in do	36,000
Waste water channel	1,03,400
	<u>30,97,110</u>

13. The quantities in the main dam, with the rates allowed will afford data for judging of the sufficiency of the estimate, and they are accordingly given in detail below.

Quantities.	Unit.	Description of work.	Rate	Amount including Contingencies
2,252	Cyft	Rock excavation in river	2 "	11,160
3739	"	do for wings &c	1 8 "	7,000
29,119	"	Earth excavation	3 6 "	16,583,300
46,686,694	C ft	Coursed rubble masonry	5 2 "	83,150
15,729	C ft	Rough rubble masonry	4 13 2 "	2,42,400
34,339,393	C ft	Brick masonry	3 8 "	1,52,100
26,0270	"	Stone archwork	8 6 "	8,170
28,414	"	Brick do	4 6 "	12,9630
26,0079	"	Hammer dressed masonry	7 3 "	32,710
11,169	"	Cut stone masonry (black stone)	1 2 6 "	
8,030 1/2	"	do (granite)	1 10 6 "	
1758	"	Beam stones &c	2 "	
11,104	"	Copying string courses &c	1 6 "	7,010
4041	Cyft	Concrete filling	3 "	16,6000
50,302	"	Earth & rubble filling	7 "	39,180
81,420	"	Embankment west end of dam	2 "	
280,000	"	do do selected earth for front	1 3 "	1,58,300
28,000	"	do do do for rear	5 "	
89,469	"	Stone pitching	2 "	
1,66,244	"	Raking & dressing	6 "	
9,481 1/2	Squares	Pointing brickwork with cement	10 "	11,300
454 3/5				
1,130				
				<u>27,16,710</u>

The most important items in this estimate are the
 Coursed rubble masonry
 Brick
 Hammer dressed
 Earthwork in embankment.

The rate allowed for the first is Rupees 8.11.6 a cubic yard and, even supposing that the whole of the material has to be brought ^{* see para. 3 above.} 5 or 6 miles, I think the rate would prove sufficient. The stone intended to be employed is found and has been used in many parts of the country; and there is every probability of its being found therefore in sufficient abundance. It is the same as that used for the new sluice at the Maxoor Tank, and which I at first supposed to be a description of limestone, but Mr Gordon tells me that it does not contain any lime. I have brought a specimen with me and its composition and character will be ascertained. ^{* Quartzite or something between limestone & trap} For bricks excellent clay is available in large quantities on the north side of the river within half a mile of the site for the dam. Wood to burn bricks is to be had in any quantities close at hand, so that Rupees 6.3.11 a cubic yard should suffice for brick masonry. The same stone would be used for the hammer dressed as for the coursed rubble masonry, and the additional rate Rupees 3.3.3 a cubic yard for the dressing appears to be ample. The rate, 2 Annas a cubic yard, for a large proportion of the earthwork in the west embankment is, I think, too low. Probably it will be obtainable most easily from the plain North east of the dam and the average

lead could hardly average less than 200 yards, seeing that an area of 265 yards square, cut down to a depth of 4 yards, would be necessary to supply the 280,000 cubic yards required. Soil could be obtained from the hill side, but there the roots of the jungle would interfere greatly with extensive excavations, even were the trees all cleared away. I am therefore inclined to think that the rate for this work should be doubled, which would add 35,000 Rupees or with Contingencies say 38,000 Rupees to the estimate, thus making the total Rupees 3,136,000.

14. The probable value of the reservoir supposing this estimate to be correct, and assuming the capacity to approximate to ^{This requires an average depth of a little over 20 feet for the area 20 square miles} 1225 millions of cubic yards may be stated as follows. To the amount of the estimate must be added charges for Permanent establishment, Home and Indian Agencies, &c. which, in accordance with the facts of the Kurnool works, may be taken at somewhat under 50 per cent. The total ultimate cost of the reservoir would then be 45 lacs, and the quantity stored for one Rupee would be 272 2/9 cubic yards. It may, looking to the character of the river, be considered that the reservoir will be full, at the time when Poombudra freshes begin to run low and require supplementing, and also that, on the average,

average, the river supply will compensate for evaporation from the surface of the reservoir — ^{This would amount to about 12,000 cub yards per hour as the maximum} during the time its supply is being utilized. — If then 10,000 cubic yards be taken as the quantity required to be stored to supply one acre of irrigation, the reservoir will, if considered only as an irrigation work, be capable of irrigating 122,500 acres. The gross revenue from which at 6 Rupees an acre would be Rupees 7,35,000 or 16 per cent on the outlay. — Such being the case there would be a considerable margin available either for extra cost of works or for the absence of a full utilization of the water. Thus supposing the works to cost Rs. 60 lacs, and the acreage irrigated not to exceed 20,000 acres, the gross return would still be as much as 8 per cent. — The figures above given may be liable to considerable modification when the information required regarding the capacity of the reservoir, the maximum and total yearly discharge of the river &c. is obtained; but they tend to show that, comparatively unfavorable as is the result of the investigations thus far in regard of the quantity of water likely to be stored for each Rupee of expenditure, there is every probability of the construction of the Vuckhailully reservoir proving to be financially desirable. —

15. With regard to Mr. Gordon's design, the only point

point in connection with the main dam which it seems necessary here to notice is the arrangement of the irrigation sluices at the Southern end. — It will be seen that training walls conduct the water for a distance of about 170 feet, and the water is then to flow into the river. This arrangement however is hardly likely to be economically practicable, unless rock sufficiently hard to stand the wear and tear of the rush of so considerable a body of water should be found with its surface not much below the level of the sluice sills, and thence sloping to the bed of the river. The existence of rock so situated has not been ascertained by sinking shafts down to it; and as, therefore, it is not actually known that rock exists at a level much above the river bed, it is clear that sluices so circumstanced may need a succession of falls below them, and this necessity might make a modification of the arrangements advisable. —

16. The investigations in connection with the proposed reservoir on this river are making good progress, but it is not expected that the field work will be finished before the close of next working season — that is — in May 1869; and it will take some months after that date to complete the designs and estimates. —

17. The work now going on is the determination of

Toonga site.

of the contour for a depth of 150 feet of water at the Baghully (Bagoli) site, together with that of a 10 feet higher level, would show the land liable to occasional submergence up to the maximum depth dischargeable at a waste weir. These contours have been determined for a great part of the length on the north side of the river, and some parts of the survey have been checked and the cross sections are being run. — On the South side of the river no new work has been done this season, and what is known of the probable reach of the Tank on that side is dependent upon former approximate surveys and levels. —

18 So far as the calculations hitherto made can be depended upon, a dam at Baghully with a depth of 150 feet of water would form a tank having an area of between 90 and 100 square miles, with a capacity of more than 3,000 millions of cubic yards. — It has been ascertained that the 150 feet level would cut the river bed above Dermootoor i.e. close to the south end of the part of the river shown on Atlas Sheet No. 12, or the length of the Tank along the river would be about 27 miles. —

19 A detached saddle about 1 mile north of the Baghully dam site has been examined with a view to the construction of a waste weir there. — It is the saddle at which the road from Shimoga to Deerthully crosses the range

range of hills; its level is 103, which is so far suitable, but there is no appearance of rock either at the road or anywhere on the hill between this point and the end of the proposed dam; and the trial pits sunk when nothing harder than tertiary gravel. — The waste weir must be capable of discharging at least 10 millions of cubic yards per hour, and in the absence of rock it is evident that the letting down of such a great quantity of water at a depth of 150 feet would cost a very large sum. A detached weir indeed has no advantages. I recommend it in cases in which the main dam is intended to be founded on hard rock, unless there be equally good rock at a level above that in the bed of the river at the weir site. — Mr Gordon himself ^{appears to} consider that the roadway saddle is practically unadaptable for a surplus work, as in the only design as yet sketched out, and that roughly, for a dam at Baghully, he has arranged for the surplus to go over the dam the falls being divided into 2 of 46 feet one of 32 1/4 and one of 25 1/4 feet. I do not doubt the practicability of such an arrangement for its safety can be ensured by receiving the overfall on a proper depth and volume of water, but it will not be advisable to try this plan on such a large scale, at least unless it be ultimately found that no better is available. —

20 There does not appear to be a probability of

of finding another saddle in connection with the Baghully site, but two miles lower down the river on the North side of what is called the Mudabai site, there is a saddle, which has not yet been examined, and at which it is probable that rock will be found, as the axis of the hill immediately South of the saddle, and on which the North end of a dam would abut, shows rock on the surface - similar to that in the bed of the river, of which indeed it is the prolongation.

21. A dam across this part of the Toonga would form such a large reservoir, at so reasonable a proportionate outlay, that it will be advisable to ascertain exhaustively what natural facilities for its construction exist. - Should however it be found impracticable to obtain a suitable site for a detached weir near this part of the river, there is another site for a dam some miles higher up which will probably do for a reservoir of large, though not of such large dimensions, as could be obtained by making a dam at one of the lower sites. This place is at the end of the hill running North North West from Mailagapett, a village on the South side of the river; and the site would be just where longitude $75^{\circ} 20'$ intersects the river. The hills on the North side are not as shown

lines on the two sides - 2,500 feet apart. - A little South of Mailagapett also there is a saddle, which has not been examined, but on the two sides of which a contour has been run, which shows that there would be no great length (about 1,500 feet) of cutting to get down to the 150 feet level, and as that is equivalent to about 100 feet depth at the river, and as with a dam here that depth would be increased, it is possible that the saddle would be found suitable in all respects for a waste weir if the rock which is apparent on the hills near the river be found to run through, and to be at a moderate distance below the surface at the saddle. - It will be seen also that the run of surplus water from this saddle to the river would be very short and direct, though the saddle is ^{nearly} 3 miles from the main dam site.

22. One year's observations of the discharge of the river have been taken, but not calculated out, since the discharges given in the Government Order as per margin were obtained. It is intended to repeat the freshet this year, and probably another season's - (1869) floods in addition will have been observed before the project will be fully matured. The project for restoring this Tank will be in a few months. - The contour has been

The Masoor Tank 23.

been completed and is being worked on the ground; the cross sections have been nearly completed and the surveys of the cultivated lands are getting on well. - It is expected that the whole of the field work will be finished by the end of the present working season, or about the 15th of May. -

24. Regarding the discharge of the Choardy, the Executive Engineer has been unable to furnish me with any additional information, but measures have been taken for the registration of the freshes of the next monsoon, and longitudinal and cross sections of the river near Chikarpore have been prepared. The new waste weir constructed by the Bombay Department of Public Works will also afford a separate means of observation, and from the two sets of observations it is expected that the discharge of the river during this season will be tolerably well ascertained. - Besides this Mr Gordon will be able to compare the rainfall and discharge of this river with those of the Coouga and Rendra and thus an approximate estimate may be formed of the relation existing between the quantity of water passing down in this year with a given rainfall, and that discharges with any other or with an average rainfall. - Now for the year 1867, the discharge of the Choardy

Square miles 540.

Choardy in which is given in the papers, printed in Proceedings of the Madras Government of the 2nd December last, No 3745, approximated to an average one is not as yet known, but it is there shown that the maximum discharge per second was 2,419 cubic feet, on the 20th July. - This corresponds to a rainfall drainage of $\frac{1}{8}$ of an inch from the whole basin, passing down in 24 hours. On the other hand from flood marks Mr Gordon estimates the maximum discharge at a little less than 15,000 cubic feet per second and this, which is equivalent to a rainfall drainage of $\frac{1}{15}$ inches, does not appear to be excessive. There appears to be no doubt whatever that the Tank, as originally constructed, did fill. Mr Gordon thinks that there is evidence to show that at the time the breach in the West bund, which ruined the Tank, occurred, some water went over the Main bund, and the Superintendent of the Nuggur Division has traced among the records claims for remission on account of the submergence of lands beyond the ordinary water spread of the old Tank, which corresponds very closely with that of the proposed restoration. - The year 1867 was an unfavorable one in the Mysore country generally, and it may be, as Mr Gordon suggests, that when the rainfall is much under the average a large proportion of the drainage is stopped by small tanks on the several feeders, while on the contrary in a better monsoon

monsoon the greater part of the difference finds its way to the main river. However further evidence of the extent of the supply is a matter of great importance, and should be obtained, as far as possible, by direct observation and be supplemented by deductions from rainfall registers, and by such information as may be obtainable from the Revenue records of the part of the country in the neighbourhood of the Sauti.

25. The plotting of the contour had not been completed when I was at Shikarpore, and the exact area of the waterspread at full Sauti level (90') and with 5 feet of water (the maximum intended) going over the waste weir had not therefore been ascertained, but from approximation from an inferior contour the full Sauti area is estimated at 40 square miles. The capacity is similarly expected to be 1,400 millions of cubic yards, and this will be determined as soon as the cross sections shall have been completed.

26. The Executive Engineer has estimated for the restoration of the Sauti on two different designs

1st by a dam across the present surplus channel above the fall, at the site of the

Bombay Department of Public Works new waste weir, with a waste weir at the present East bund of the old Sauti.

2nd by a dam and weir combined across the present

Vide enclosed Plan II.

Plan II.

present surplus channel. - The designs were worked out in the order above given. - The general character of the first dam will be seen from its Cross Section which is given in Plan N^o III. - It was intended to have a lower and an upper set of sluices for passing irrigation water, the water from the upper set being allowed to drop through a modified arrangement of the gates fall used in the North-west provinces. - For the surplus work at the East bund two arrangements were planned. - The fall to be overcome between the crest of the waste weir and the bed of the Choardy near Soototta would be about 120 feet; and, in addition to the overfall at the waste weir itself, 6 masonry falls were planned. - The length of the crest of the waste weir was to be 370 feet and the greatest depth of water passing over it was to be 5 feet. - There is a natural line of drainage, in the shape of a small nullah, running in the direction which the surplus water would take if discharged at this point, and the distance from the weir to the Choardy, would be 2,600 yards. Such a weir would be capable of discharging 1,992,820 cubic yards per hour or 14,946 cubic feet per second. The cost of surplus works so arranged would be Rupees 6,04,660. The alternative arrangement, while retaining the same design for the weir, omitted the masonry falls in the surplus channel, and contemplated allowing

allowing the water to cut down until a sufficiently hard substratum might be reached to prevent further action. The estimated cost of this plan is Rupees 367,970. No borings have been made on the line of the channel to ascertain what would probably be its ultimate level at various points, and it is clear that it would be necessary to ascertain this with considerable accuracy, in order that the retrogression of levels near the weir might be effectually guarded against. The ultimate expense of either of these systems would be very problematical. The maintenance of weirs in the first case would in the absence of rocks on which to found them necessarily entail a considerable expenditure yearly, even if the estimate proved to be approximately correct with regard to the first cost of making them efficient. The second plan would, even were the result of borings altogether satisfactory, certainly require much additional expenditure, above the first cost of the weir itself, for rendering its tail secure, and for preventing the deepening of the bed up to such a distance below as would ensure freedom from leakage through the subsoil on which the present bund stands. Mr Gordon thinks that there is rock between the hills connected by that bund, and if so it may be of such an extent and character as to make the construction of a weir here practicable at a moderate

Plan III.

moderate expense, but the surplus water ¹² could not be allowed to cut its own channel ⁹ below the weir unless it were first clearly ascertained that the rock under and below the weir would not be liable to injury either by undermining or by the effects of the overfall, even were the channel lower down to cut away to the greatest depth which borings might show to be possible. The cost of the masonry dam, in connection with either of the above waste weirs, would be Rupees 847,550. The proposed expenditure on the old main bund is Rupees 91,600, so that the cost of the project on the 1st plan would be Rupees 15,43,810 and on the 2nd plan Rupees 13,07,120.

27 The difficulties attending an arrangement for the discharge of surplus water at the East bund having thus been found to be very considerable, Mr Gordon turned his attention to framing a design for a dam at the present surplus channel, which should serve both for retaining the tank water to the necessary level, and for discharging whatever surplus might thereafter be received. The general features of this arrangement are indicated in Plan N^o IV, and are as follows.

At about 190 feet below the point, where the
Boribay

Bombay Irrigation Department have constructed a dam wall across the surplus channel, is the ledge or reef of rock over which the river falls some 30 feet into a basin in the rocks below. On this reef it is proposed to build a dam wall having a length of 150 feet, a top width of 5 feet and its crest at 14 feet above datum. In this dam ^{all of new sluices in its main body.} there are to be six sluices 3' x 5' for the regulation of the discharge when necessary. At a distance of 60 feet above the lower edge of this weir is a second or intermediate dam, having its crest 33 feet above datum, and having in its body 7 sluice vents of 4' x 9' each. The length of the crest of this dam is to be 109 feet, and the maximum depth passing over would be 8.56 feet. The water passing over this dam would fall into a basin with hard rock bottom, over which there would be a minimum depth of 12 to 14 feet and a maximum of 24 $\frac{3}{4}$ feet. 145 feet above the intermediate, will be, according to this design, the main dam having a width at base of 70 feet, with its crest arranged in two falls, the upper at a level of 37 $\frac{1}{2}$ feet above datum with piers $\frac{1}{2}$ feet high, and the lower at 77 $\frac{1}{2}$ feet, with water cushion having a minimum depth of 9 and a maximum of 15 feet. From the crest the overfall will be 46 feet to the level of the crest of the 2nd dam and the minimum

minimum depth of water to receive the fall will be 33 feet and the maximum 41.56 feet. 28 It appears to me that the arrangement just described is altogether preferable to that by which the surplus water would be discharged at the East end. In either case the water has to be lowered the same depth, viz: the difference between full tank level and ~~the~~ the bed of the Choultry; while in the one case there is rock, the quality of which is known, and which has stood the wear and tear of the whole discharge for many years, and in the other there can be at best only untried rock, and it is doubtful whether anything harder than partially decomposed granitic rock would be found at all. The difference of expense though important is nevertheless a secondary consideration, it being of the first consequence to obtain a safe design, and in my opinion the system of divided falls with water cushions is not only the safer after the completion of the whole works, but it admits of the works during construction being carried on without any serious risk. The 3rd or lowest dam may be built first, and the others can be raised successively just so fast as circumstances may dictate; and a fresh in excess of the capacity of the sluices might pass over the walls at any stage of their progress without occasioning any damage of consequence. The ^{small} dam on the edge of the falls could be completed in a few months, and there need, I think, be no doubt of its stability as the overfall will

he received into a basin of considerable depth, and the rock there having stood an overfall of 30 feet for a great number of years would probably not be affected by the additional height of the proposed overfall, and extent which would be likely to undermine the dam, though it is very possible that the pool may be somewhat deepened. There would be time before damage had become imminent to provide a remedy, and this remedy would be simple and inexpensive, as the most that would be necessary would be the reduction of the fall within safe limits by the construction of another wall across the pool below the 3rd dam. The security of the intermediate and main dams will depend mainly on the depth of water in the basins below them, and the depths provided by Mr Gordon appear to be sufficient. By the formula used for the water cushions of vertical falls in the North Western Provinces the depth of the cushion of the greater fall would, for brickwork, be 17.98 feet, while that allowed here with a hard rock bottom, is 33 feet or perhaps more correctly 35.86. Similarly below the 2nd dam the cushion required by the formula would be 12.54 feet, and that proposed is 16.19 feet. I have quoted this formula because it has, I believe, been successfully applied to the falls on some of the Canals in the North West, but

$$\begin{aligned}
 D &= 1.55 \sqrt{h} \times \sqrt[3]{5d} \\
 &= 1.55 \sqrt{43.5} \times \sqrt[3]{56} \\
 &= 17.98.
 \end{aligned}$$

$$1.55 \sqrt{16.81} \times \sqrt[3]{58.56}$$

$$1.55 \sqrt{829} \times \sqrt[3]{15}$$

but I do not know on what principle it is based. It perhaps errs in giving too small a depth of cushion for high falls. The extreme example of proportion between cushion and fall, with which I am acquainted, is that of the Rajah fall at Gairsoppa, the height of which is 829 feet and the depth of the pool 130 feet. I do not know what the maximum depth going over would be, but I think not more than 13 feet, the cube root of which would be nearly 2.5 making the depth of cushion for brickwork, according to the formula, 107.95 feet, which is too little by about one fourth. For stone masonry to which rock would more nearly approximate the depth of cushion allowed by the formula would for the same fall be 71.97 feet or not much more than half the actual depth at the Rajah fall.

29. A great advantage of this system would be, under the circumstances of the site, that it is not likely that any expensive additions will be needed to supplement the works as originally carried out. The existing rock and the water will, between them, absorb the forces generated and the artificial dams will be subjected to nothing more than the wear and tear of the body wall of an ancient, which is nearly always inconsiderable.

30. In order however to secure the satisfactory action

action of the water cushions, it is essential that the sluices in the several dams be fully under command, in order that the first and second basins may always be full when any water begins to pass over either the main or intermediate dam. All the sluices should therefore be capable of being worked at all times, and this can only be done by placing the gear connected with them on platforms above the maximum level of the water.

31. I should be disposed to omit the posts on the first crest of the main dam, and to put the sluices which will be needed for the discharge of irrigation water at the two ends, where their platforms, which must be above the 95 feet level, will not interfere with the crest of the weir. The lower sluices should be at the base of the dam for it would be much better to place them here than to give additional low level sluices in the old main bund. A second set might be placed about 30 feet above datum, but as, by means of the intermediate dam, the lower set could always be worked under a head not exceeding 57 feet, and as this gives a pressure of less than two atmospheres, there would be no difficulty whatever in providing suitable gear for regulating openings of 3 to 3½ feet diameter.

32. The section of the two crests of the main dam might also be altered with advantage, so as to bring the rear edge of the crest to the face of

a vertical, or nearly vertical, wall—the width of the water cushion can be somewhat widened, and the floor should be an invert with a sufficiently high reversed sine to prevent the possibility of the displacement of any of its stones.

33. The estimated cost of the dam with water cushions is Rupees 775,462; and probably, after making such modifications as will tend to secure its entire efficiency, the estimate will not exceed 9 lacs.

34. The proposed expenditure on the old main bund amounts to Rupees 91,600 and provides for raising the earthworks, where necessary, to 103 feet above datum, and for completing and raising the revetment to the 101 feet level. I think however it will not be prudent to rely on this old bund being watertight. Probably it is so and its enormous thickness makes it unlikely that any of those causes, such as rat holes, faults from settlements &c. which commonly lead to leakage can exist to a prejudicial extent. Still all risk should be avoided, and I would therefore place a thick wall of puddle behind the revetment. As however the interior slope of the bank is everywhere flat and in some places as flat as 1 in 5, the puddle would have to be arranged in steps, and in this manner it could be inserted without necessitating the removal of any very great quantity of the old soil. The minimum depth of rammed soil between the puddle and the revetment

ment might be 4 feet. - The width or thickness of the puddle at base 25 feet and, at the 96 feet level, 3 feet. - The head of the existing sluices will have to be carefully secured.

The financial merits of this project - cannot of course be accurately ascertained, until present deficiencies of information shall have been remedied. - The subjoined estimate however will give some idea, and I hope one not too sanguine, of the probable results of restoration of the tank. -

The masonry dam may be taken as likely to cost

Estimate for old main bund	9 lacs
And for puddle - say	40,000
Securing sluice heads	10,400
Home and Indian Agency and Permanent Establishments	4 1/2 lacs
Total	15 lacs.

it with regard to the probable supply. Lieutenant Smith of the Bombay Department of Public Works estimates the discharge of the Choordy in 1867 at 27,645,440. - The area of the drainage basin is from 1,500, to 1,600, millions of square miles, so that the above discharge represents a fall drainage of about 6 1/4 inches during the year. - To fill the tank, a drainage of, in round numbers, 36 inches is required, and I do not myself think that this will be received except in very favorable years, for the Choordy basin, though well within the South west monsoon, very differently circumstanced to the upper parts

7180 acres.

parts of the Poona and Budra. - The average supply may perhaps be the equivalent of 20 inches of drainage or say 800 millions of cubic yards. - The irrigation under the tank and river yards. - The irrigation under the tank and river yards in the Bombay Presidency in 1866/67 was not very extensive, but it appears to be expected that this area will be extended sufficiently to absorb 110 cubic feet per second and this is stated to be enough for $50 \times 110 = 5,500$ acres of rice throughout the year, which may be put, as regards total quantity of water required, as equivalent to 13,000 acres for a single crop. - Allowing 10,000 cubic yards as the storage for 1 acre, the Bombay irrigation would absorb 130 millions of cubic yards - 150 millions will therefore be taken as the quantity for which the Company would obtain no returns. - Evaporation will, as regards this reservoir, be a not unimportant item. The area of the tank, when containing the average supply (800 millions cubic yards) will probably be about 28 square miles. - The average area from which evaporation will take place during 6 months may be assumed to be 16 square miles, or 40 millions of square yards, and at 1/4 of an inch per diem the quantity evaporated in the 6 months will be, in round numbers, 150 millions of cubic yards. -

36. It appears then that the average quantity of stored water which will be available annually for transmission to the Company's Canals, under the Poombudra will be about 500 millions

C. H. 7,464,308,300 which however appears to require correction to 7,464,268,000

millions of cubic yards, or enough for 30,000 acres. The gross returns therefore, at 6 Rupees an acre, would be 3 lacs or 20 per cent on the supposed outlay, 15 lacs, required for the carrying out of the project.

37. I have been obliged to estimate the value of the water stored in terms of the area capable of irrigation thereby, this being the readiest and most intelligible way of expressing it, but it is very probable that, should the Company construct these reservoirs, a good deal of the water will not be so utilized, but will be used for maintaining navigation throughout the year on the Kurnool Main Canal, and on any other Canals which may hereafter be constructed. I have however little doubt that, except for the very short time in each year during which there will be no cultivation going on anywhere, there will ultimately be but very little water which will not be employed in rendering cultivation secure, as well as for navigation. Fully to develop the Kurnool works somewhere about 60,000 cubic yards an hour for 6 months need to be provided by storage, and the total quantity would therefore be 2592 millions of cubic yards or say 2600 millions. Nothing but experience will afford entirely safe grounds for estimating the value of large reservoirs, but the circumstances of the Company's Kurnool Canal appear to me to offer a particularly favorable opportunity for ascertaining

ascertaining that value, seeing that it requires no elaborate argument to show that a perennial, or nearly continuous, water supply, with the 2nd crops, and more efficient navigation, therefrom attainable, would not only increase the revenue largely, but reduce the relative cost of maintenance in almost direct proportion to the increase of receipts. It is indeed not improbable that it would be worth while to spend half the cost of the Kurnool Main Canal, which for present purposes may be supposed to be 160 lacs, in the attainment of this object. The Masoor reservoir project is from its comparatively moderate dimensions, and estimated cost, better fitted than any other, which has thus far been brought under notice, for a first experiment, and I hope it will be so brought forward by the Company as to leave no important point, upon which information can be obtained, in doubt.

38. As regards the interest of the Bombay Government in the supply of water from the Choardy, there would seem to be no difficulty in providing, by arrangement, for its security to the fullest possible extent. The Bombay Irrigation could not possibly be injured by the construction of the reservoir by the Company, and no doubt the latter would be perfectly ready to provide all necessary facilities for

for affording, without payment, whatever quantity of water, within the limit which may be agreed upon, may be required from year to year as cultivation is extended.

39. On the receipt of Proceedings Madras Government No. 3745 of the 2nd December last, addressed the Agent in accordance with the instructions therein given, but have not as yet received a reply. - I may however with reference to para. 5 of the Report of the Chief Engineer for Irrigation, Bombay, printed with these Proceedings, state that the Maxoor Reservoir will not be within the Bombay Presidency, the old tank and the proposed restoration being in the Mysore territory, though whatever irrigation there is under it is in the Bombay limits. - The Company have for many years been endeavouring to find suitable sites for reservoirs, and they have, as yet, only found three which are likely to prove feasible both as regards facilities for construction and reasonableness of cost. - The Company have not, in order to save trouble, desired to interfere with existing interests and to benefit by the transference of property properly belonging to others, but their officers found the remains of a remarkably fine reservoir very favorably circumstanced for restoration, and learning that it had remained in a ruined state for an indefinite number of years, and that no attempt had been made, or was in contemplation,

contemplation, ~~to~~ turning its capabilities to account, they proceeded to ascertain what those capabilities were; and if, as I have supposed, arrangements can be made for meeting the fair requirements of the lands in the Bombay territories, and if, as appears probable, there should be enough water still available to make the construction of the reservoir by the Company remunerative, I hope ~~the~~ the proposition to do so will receive every encouragement from this Government, which can properly be offered.

I have the honor to be,
Sir,
Your most obedient servant
Colonel G. H. D. Company
One Capt. for L. H. Company

Dec. 1868
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J. B. H. 1868
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The Secretary to Court
A. B. H.

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Enclosure 5
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