(1) பக்கங்களின் எண்ணிக்கை 54

(2) புதுக்கித் திருப்பிய நாள் May 88

(3) ஆதாரங்குறிப்பவர் கருக்கொப்பம் [illegible]

தமிழ்நாடு ஆவணக் காப்பகம்.

தமிழ்நாடு அரசு

பொதுப் பணித் துறை

அரசாணை எண். 1000 W
மு. கோப்புத் தாள் எண்.

அச்சகம்
பலவகை

நாள் : 28-3-1890

198 .

மடிக்கவோ கண்டபடி கையாளவோ கூடாது

ஆவண. கா-1—18,000—15-6-87.

1000.

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Buildings and Roads.
Military Works.

READ—the following paper :—

From Major-General E. H. H. COLLEN, C.I.E., Secretary to the Government of India, Military Department, to the Secretary to the Government of Madras, Public Works Department, dated Fort William, 4th January 1890, No. 19 M.W. (Cantonments—Water-supply).

I am directed to acknowledge the receipt of your communications marginally noted, relative to the provision of a water-supply for the cantonment and town of Bangalore, and in reply to state, for the information of the Governor in Council, that the Government of India, after careful consideration, have decided to place the preparation of a definite project for this work in the hands of the Inspector-General of Military Works in communication with the Resident in Mysore.

No. 3432, dated 3rd December 1889.
" 1683 W., dated 27th June 1889.
" 1327, dated 18th May 1889.

ORDER—dated 18th January 1890, No. 154 W., Public Works.

Recorded.

(True Extract.)

(Signed) R. R. E. DRAKE-BROCKMAN, Lt.-Col., R.E.,
Ag. Joint Secy. to Govt., P.W.D.

To the Military Department.
" Superintending Engineer, V Circle.
To J. C. Larminie, Esq., Executive Engineer.

Exd. P. L. Pereira.
Spare Copies

BUILDINGS AND ROADS.
MILITARY WORKS.

Govt. of {1890} Madras.

PUBLIC WORKS.

Dated January, 18th.

Recd.

Encl.

G.O., 18th Jan. 1890, No. 154 W.

JANUARY.

Water-supply for the Cantonment and Town of Bangalore

Letter from the Government of India stating that it has been decided to place the preparation of a definite project for the — in the hands of the Inspector-General of Military Works in communication with the Resident in Mysore, recorded.

2/1000

18TH MAY 1889, No. 1326 W., PUBLIC WORKS.

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Buildings and Roads.
Military Works.

READ—again the following paper :—

G.O., dated 16th July 1888, No. 2147 W., Public Works.

Note by the Chief Engineer, Public Works Department, dated 7th July 1888.

Order—dated 16th July 1888, No. 2147 W., Public Works.

The investigations made of late years with the object of obtaining a pure water-supply for the troops stationed at Bangalore having failed to produce an efficient and economical scheme, the Government resolved to offer a reward of Rs. 1,000 for the best essay on the subject on the conditions specified in the notification published in the *Fort St. George Gazette* of the 1st November 1887 and subsequent issues, the award being left to the Chief Engineer, Public Works Department.

2. A number of essays have been received in compliance with this invitation, and have been carefully examined by the Chief Engineer, who awards the prize to Mr. Standish Lee, Sanitary Engineer, Mysore. The sum of Rs. 1,000 will accordingly be paid to Mr. Lee by the Executive Engineer at Bangalore, and will be adjusted against Military Works under instructions from the Examiner, Public Works Accounts.

3. The essay submitted by Mr. A. H. Garratt, Executive Engineer, Bellary, is, in the opinion of the Chief Engineer, a very good one, and does him great credit. The essay of Mr. S. Tomlinson, Deputy Chief Engineer, Bombay Water Works, is also, in Colonel Hasted's opinion, a very creditable paper. Both these essays came near to winning the prize.

4. A copy of these Proceedings will be published in three successive issues of the *Fort St. George Gazette* for the information of competitors."

(True Extract.)

(Signed) J. O. HASTED, Colonel, R.E.,
Secretary to Govt., P.W.D.

READ—also the following papers :—

From Sir H. N. D. PRENDERGAST, K.C.B., V.C., Officiating Resident in Mysore, to the Chief Secretary to the Government of Madras, dated Bangalore, 22nd December 1888, No. 4366/371-8.

I have the honor, with reference to your letter No. 479, Political Department, dated 14th July 1888, to forward copies of a letter* from the Dewan, and of a memorandum by the Secretary to Government, Public Works Department, Mysore, on the subject of Colonel Hasted's note on the Bangalore water-supply.

* No. 19, dated 3rd December 1888.

2. I am of opinion that Sankey's reservoir is capable of improvement, so that it might be far more useful than at present, and there is no doubt that water from the Hebbal tank can be raised to supplement the supply for the civil and military station and the garrison, or that a supply for the civil and military station and troops can be pumped from one of the tanks near the head of the Pennakini river, or that a good supply, far more to be relied on than any of the above, can be stored in the Hassargutta tank in the Arkavathy valley; but the object of the Madras Government seems to be to obtain the purest water available for the troops at a moderate cost, and I think that the cleanest source of supply within ten miles of the barracks is the streamlet, an affluent of the Arkavathy river, that might conveniently be impounded near the 5th milestone on the Mágadi road.

3. Mr. Larminie has been deputed to examine the projects for obtaining water from the Arkavathy and Pennakini valleys; when his reports give the means for ascertaining which project is capable of giving the needful supply at the cheapest rate, it will be possible to determine whether one reservoir should supply the troops and the civil and military station, or the troops and the pettah, or the troops and both station and pettah.

4. When a project has been selected for execution, it will be a fit time to settle the respective rights of the Government of India and of the Government of Mysore to the water in Sankey's reservoir.

Enclosures.

From K. SHESHADRI IYER, Esq., C.S.I., Dewan of Mysore, to the Resident in Mysore, dated Mysore, 3rd December 1888, No. 19.

In reply to your office letter No. 2448/288 of the 18th July 1888, forwarding, for the opinion of His Highness the Maharajah's Government, copy of a note by the Chief Engineer, Public Works Department, Madras, on the subject of the water-supply of Bangalore, I have the honor to forward herewith, for your information, copy of a note thereon by the Superintending Engineer of Mysore, which gives expression generally to the views entertained by the Durbar regarding the merits of the various schemes proposed.

2. I fully agree with Colonel Hasted in his opinion that Sankey's reservoir cannot contain a pure supply so long as the rifle ranges remain in their present position at the head of the basin. Their removal, I would add, appears equally necessary, whether the reservoir is intended to supply the pettah or cantonment. But this reservoir by itself is, in my opinion, quite insufficient for the supply of the pettah. Colonel Hasted (in para. 22) estimates that it will supply a population of 50,000 at 4 gallons a day. Experience in the Mysore city, where only a few fountains have yet been erected, goes to show that about 6¼ gallons would be the lowest rate per head which any proper water-supply scheme should provide for. The Durbar are already carrying out some works intended for a supply to a part of the pettah by means of the leakage from Sankey's reservoir. The supply thus obtained has to be considerably supplemented before a suitable scheme for the pettah can be worked out. Both by reason of proximity and the lower lift required, the Mágadi valley is more appropriate for the supply of the pettah than that of the civil and military station, but the Durbar will refrain from any further investigation of the capabilities of this valley for the pettah supply until some definite decision is arrived at by the British Government as to utilizing it for the civil and military station and the troops.

3. On the subject of the use to which Sankey's reservoir is to be put, I have nothing to add to the observations in Mysore Public Works Department Secretary's letter to Assistant Resident, No. 1548/268, dated 14th April 1888, nor do I consider it necessary in this place to refer to the very unreasonable views entertained by the station municipality on this subject. The Durbar will gladly agree to any arrangement which is convenient to the British Government. They would gladly have the full use of this reservoir so as to be able to utilize it for the partial supply of the pettah, and in that way obtain some return, however small, for the large capital sunk in it. Or, if the British Government prefers to utilize it for the supply of the troops and the station in accordance with the original object of its construction, then in that case the Durbar will be satisfied with receiving some moderate return therefrom, as contemplated in the orders of the Government of India in letter No. 384 C., dated 25th June 1869.

4. Under such circumstances it appears to be somewhat premature now to discuss the question of any exchange as between this reservoir and the Mágadi valley, which is mooted

by Colonel Hasted in para. 22 of his note, and I have only to add that the Durbar will offer every facility in their power for the investigation and execution of the Mágadi valley or any other scheme by the British Government.

NOTE.

The Chief Engineer's note on the Bangalore water-supply deals with the several essays submitted in response to the notification of the Madras Government offering a premium for the best solution of the water difficulty. In so far as Colonel Hasted's recommendations affect Mysore, I have to offer the following remarks.

2. The first point requiring consideration and settlement is the right to Sankey's tank, the subject of paras. 2, 3, 4 and 5 of Colonel Hasted's memorandum. In my note of 14th April 1888, I endeavoured to explain, so far as I could, the position of the Mysore Government in regard to this tank, my remarks concerning which appear to me still to hold good. Colonel Hasted observes, however, that whilst the expenditure by the Mysore Government of nearly 5½ lakhs on the works constitutes a decided claim on their part to the tank-supply, the contention of the municipality that the surplus revenues of Bangalore may be assumed to have met the expenditure should not be lost sight of. In disposing of this argument it must not, I think, be forgotten that prior to the rendition the surplus revenues of the province as a whole were given to the Public Works generally, according to the necessities of the various claims and in the order of their relative importance, and the net result of this expenditure of the surplus revenue was, in consequence of the famine, a State debt of 80 lakhs at the rendition. It is not unreasonable for me to infer that, had the Oopparhully water-supply scheme never been attempted, either this debt would have stood at 74½ lakhs, instead of 90,* or that the 5½ lakhs spent thereon would have gone to other works from which the Mysore State would now be deriving a direct benefit; or, had the scheme proved a success, the Municipality and the Military Department would now be paying to the Mysore Government a moderate percentage on the outlay incurred. As it is, not only does the burden of the outlay rest on Mysore, but the municipality claim sole right and title to the results of that outlay and decline to meet any charges whatever therefor. However, an early settlement of this question is most desirable. As matters now stand, the Public Works Department of Mysore are hampered by the rival claims of station and pettah and have to incur an annual outlay on the maintenance of its feeders, without being able, at same time, to improve them in any way.

* This should be 80.

3. I may note here an error in para. 4 of the memorandum, into which Colonel Hasted has apparently inadvertently fallen, as regards the possible reduction of loss by leakage. It was to 16 million cubic feet, not to a mean between 12½ and 15 million, that Major Kensington thought, might be reduced the loss from evaporation and leakage combined, which General Mullins computed to be 20½ million cubic feet.

4. As regards the merits or demerits of General Fischer's Hebbal scheme and Mr. Standish Lee's Mágadi road valley scheme, I have already submitted brief notes embodying my views. Both these involve the cession of land appertaining to Mysore, but until it is decided finally whether one or other of them is to be taken up, the question of compensation need not be worked out.

5. As regards the second Pennakini drainage scheme, Major Kensington's, I have not had the opportunity of going into it carefully, but I have personally expressed to Colonel Hasted what I thought about it. I agree in his remarks thereon, paras. 13, 14 and 15. I doubt whether on this scheme being thoroughly worked out it will have any special advantages over a modified project for the Hebbal tank. Here again compensation would be a serious element, and the interference with the supply of other tanks will have to be considered.

6 The only other point in the papers in which Mysore is directly interested is the decision of Colonel Hasted, recorded in his para. 22, that the troops and the civil and military station should receive their supply from the Mágadi road valley, Sankey's tank being left for the supply of the pettah. The Mágadi road valley, it is clear, is the most suitable place for the supply of the pettah, and this being the case and Sankey's tank not affording an ample supply, however much we may improve it, it is not obvious why the pettah should relinquish its claims to this valley in favor of the civil and military station. The troops only might certainly draw their supply from this valley without detriment to the pettah, and if the Mágadi road reservoir is to be constructed, it might be utilised for the troops and the pettah, not for the troops and the civil and military station, the cost being borne by the Military Department and the Pettah Municipality, in the proportion of the quantity of water drawn off by each. I presume the Pettah Corporation will not object to such an arrangement, and will be prepared to meet their share of the outlay necessary.

7. The proposal that the rights to Sankey's tank should be a set-off against the grant of the Mágadi road valley by Mysore for less than the actual value of the land is hardly a fair one, as the title to Sankey's tank stands on grounds altogether apart from the question now raised. This would be equivalent to making Mysore pay more for Sankey's tank than they have paid already without obtaining therefrom any adequate return.

8. If what I have advanced above meet with approval, the project to be worked out would be the construction of a service reservoir near the pettah to be supplied from the Mágadi road valley with water sufficient for 50,000 people, *minus* what can be sent down from Sankey's tank, *plus* 60,000 gallons for the troops. The cost of this to be borne by the Military Department and the Pettah Municipality in the proportion of the water given to each. The Military Department would then set up their Ulsoor engines, pumps, and mains to send up the water from the above service cistern to the service cisterns in the barracks.

BANGALORE,
27th July 1888.

(Signed) C. BOWEN, R.E.,
Supg. Engineer, Mysore P.W.D.

Transferred to the Public Works Department.

9th January 1889.

(Signed) J. F. PRICE,
Chief Secretary.

REPORT by J. C. LARMINIE, Esq., dated 2nd February 1889.

Report to accompany the estimate for Water-supply to the Cantonment and Garrison of Bangalore and to the estimate for supply to the Garrison alone.

In accordance with No. 3 reference, instructions were given for the investigation of two schemes for the supply of water to Bangalore.

First, that proposed by Mr. Lee, to whose essay was awarded the reward of Rs. 1,000 (reference No. 2), and second, that proposed by Major Kensington.

2. The instructions given were general, and were to the effect that every item composing the estimates was to be gone into in minute detail and most carefully estimated for.

References.

(1) Letter from the Government of India, No. 1182 M.W., of 14th June 1887, recorded in G.O., No. 1924 W., of 18th July 1887.
(2) G.O., No. 2810 W., of 20th October 1887.
(3) Chief Engineer's note printed with G.O., No 2480 W.—A, of 14th August 1888.
(4) Chief Engineer's note printed with G.O., No. 25 W., of 8th January 1889.

3. Accordingly, some time was devoted to consideration, from every point of view, of each detail. Mr. Lee's, commonly called the Mágadi road scheme, being the most promising, was first taken in hand.

4. The country was carefully examined to secure the best site for the dam, as also for the best and most economical line for the supply main to Bangalore, and endeavours were made to obtain further data regarding rainfall and run-off.

5. Some time was also devoted to the preparation of a fairly accurate survey with levels and contours of the proposed Mágadi road reservoir, site and the design of the masonry dam was made out in detail.

6. According to somewhat modified instructions received in December, approximate estimates, to admit of a comparison of the various schemes, were considered in the first instance sufficient. Had it been understood that sketch-plans and estimates were only required, the work could have been done much sooner; as it is, the projects are now submitted well within the two months mentioned (reference No. 4). However it is hoped that the time which has been devoted to minor detail will be of value hereafter; for, of the estimates herewith submitted, that for the Mágadi road scheme has been prepared in considerable detail, and is believed to be a very close approximation of what the work may be expected to cost.

Reference No. 4.

7. To the Nagavaram scheme, that for the Hebbal tank, and for the smaller scheme for the garrison supply (instructions regarding the two latter received in December last) it has not been possible to devote so much attention. The surveys and estimates are, however, believed to be close approximations.

8. The accompanying comparative statement gives the leading features of the several schemes and their estimated cost. Each scheme will now be reviewed in detail. They have all been based on the same general data as laid down in the Chief Engineer's note, and regarding which a few observations may, it is hoped, be permitted (*vide* paras. 12 to 18).

Reference No. 4.

9. The more correct name for this scheme would be Maligal, near which village * it is proposed to construct the reservoir. The catchment area of 9 square miles (as measured on the Topographical Survey, *vide* sheets 42 and 63) extends 3 miles to the north and 1 mile to the south of, 2 miles of the road from Bangalore to Mágadi (4½ to 6½ miles).

Mágadi road or Maligal scheme.

10. In every particular except cost, it is by far the most promising of the three schemes investigated for the supply of the cantonment and garrison. But, provided a scheme is admitted to be promising in other particulars, the mere question of even a few additional lakhs to the cost should not, it is thought, weigh much against it. The comparative statement shows the small additional quantity of water† (some 20 M.C. feet extra for a year's supply) which has to be stored to provide for loss from evaporation, leakage, &c., owing to the favorable conformation of the reservoir site, a narrow deep valley, the area of waterspread at F.S.L. being 85 acres.

Advantages of Maligal scheme.

11. The other advantages are—

(1) The whole of the catchment may be considered free.
(2) Probably not more than one-sixth of the area is at present under cultivation; there is, however, a growing tendency to extend it, chiefly casuarina plantations; so the Mysore authorities have been requested to check its further extension for the present.
(3) The catchment area chiefly consists of steep, bare lateritic hills, from which personal observation showed that even moderate showers are very quickly run off (*vide* also para. 18 of Chief Engineer's note, reference No. 3). In this connection also *vide* paras. 17 to 19 regarding percentage of run-off.
(4) Analysis of the water taken from the stream under unfavorable circumstances—shortly after a flood—shows it to be remarkably pure, and the accompanying table compares it with water from the other sources, as also with that now pumped up for the use of the Bangalore garrison. Even in the driest season there is, it is stated, a small stream of pure water always flowing.
(5) A supply for more than one year can be more advantageously stored here than elsewhere.

12. Regarding the quantity of water to be stored, *i.e.*, 40 M.C. feet or only *one year's* supply. As a comparison between the various schemes, it may suffice to estimate for storing this quantity; but it is considered that with only one year's supply in store a bad season or two cannot possibly be tided over.

Quantity of water to be stored and run-off catchment area.

13. The minimum supply, 7 M.C. feet per square mile of catchment, which according to the accepted Mysore data might always, it was thought, be expected to flow off, cannot, it is *now found*, be counted on as a certainty.

---

* Situated about one mile below the bridge over the stream at furlong stone 5/6 on the Mágadi road.

† 40 M.C.F. required for supply of the cantonment and garrison, so 60 M.C.F. must be stored for a year's supply.

14. Seven M.C. feet means 3·01 inches of rain run-off each square mile. Taking 17″ as the lowest rainfall, 3·01″ would be almost 18 per cent. of that total fall, while there is abundant evidence to show that, to obtain so high a percentage, the fall must be in sharp heavy showers. Everything depends on the character of the rainfall. In the course of only an average year's fall (36 inches) *provided* that some of the falls come down in quick heavy bursts, the 18 per cent. might safely be counted on, while light continuous rain, although the 24 hours' fall might be high, would yield a much smaller percentage.

Experience of 2nd November last. Light continuous rain 5 inches in 24 hours. Percentage received by Sankey's tank 13 per cent.

15. The lighter the annual rainfall the smaller and fewer are the chances of obtaining heavy showers of short duration, so that in a season of minimum fall it may happen, and very probably will, that the run-off, instead of being 7 M.C. feet per square mile, will be almost *nil*. (This it is known on the best authority has already been experienced at the Mysore water works.) Consequently how essential would it not seem to store as large a supply as can consistently be done?

16. Two and even three years' supply have been advocated. The reports that have during these investigations from time to time been submitted regarding the Mágadi road scheme advocated the storing of 1½ years' supply (60 M.C. feet), which requires, allowing for waste, evaporation, &c., as near as can be 100 M.C. feet in the reservoir (*vide* table of consumption and waste).

17. That this quantity can be impounded in an average year is hardly open to question. The Mysore data gives 11 M.C. feet per square mile as the *average*, as deduced from Sankey's tank, a most unfavorable catchment. As noted in para. 18 of Chief Engineer's note,* the run-off of the Mágadi road catchment must be higher, and observations made during the course of these investigations give the following approximate results.

* Reference No. 3.

18. During the period 11th September to 2nd October last, the total fall from certain selected showers was 5·4 inches. This fall over the catchment (taken as only 8½ square miles) means 106·63 M.C. feet.

The quantity that passed down the stream was approximately computed to be 42·71† M.C. feet $\frac{42{\cdot}71}{106{\cdot}63} = 0{\cdot}4$ or 40 per cent. average. Individual falls gave for half an inch in 1½ hours (*after a long period of draught*) 3 per cent. Even on this occasion the stream began to increase half an hour after the rain commenced.

† Sufficient for a year's consumption.

		PER CENT.	
For a 2 inch fall		58	
„ 1·3 „		29	
„ 1·1 „		40	
„ 0·5 „		30	Catchment by this time well wet.

All these were falls of short duration from 1½ to 3 hours.

19. But although the data is admittedly very approximate, still it suffices to show what may be expected in an average year. The year under reference was, however, under the average, as the total fall was only 34 inches.

20. To impound 1½ years' supply, 100 M.C. feet, 4·78 inches of rain must run-off the 9 square miles of Mágadi road catchment, or only 13·3 per cent. of an average year's fall.

21. The dam, to impound this quantity, should be 9½ feet higher than that for one year's supply now estimated for (see section), and the *additional* cost, as per detailed estimate, for a masonry and concrete dam for the full width of this section would be Rs. 77,630.‡

	Rs.
‡	2,70,370
	1,92,740
	77,630

22. The advantages of the scheme are detailed in para. 11. The chief disadvantage will now be alluded to: it is that the run-off being so very quick the water, even in small freshes, comes down highly charged with silt. It is consequently proposed not to draw off water below 13 feet above bed of stream at site of dam (level 33·48 on survey), thus utilizing a length of the river bed as a silt trap; with a view to keep this clear it is proposed to place two or more 3-foot iron pipe scouring sluices worked by equilibrium valves in the foot of the dam, and a special design for these valves has been partly worked out. But even with all possible precautions it is feared that silting up will go on.

Disadvantage.

23. Messrs Richardson and Cruddas, the well-known Engineering firm of Bombay, have taken considerable trouble in furnishing particulars and cost of the best description of pumps and engines to work against the heavy heads involved in the three schemes, that of Mágadi road being greatest. The heads in each case have been deduced as follows, Mágadi road being taken as an example:—

Pumping engines.

Top water-level in settling ponds	3,090·0 M.S.L.
Lowest off-take at reservoir	2,741·71
Actual lift ...	348·29 feet.
Pumps can be placed 25′ above draw-off	25
	323
Head allowed to overcome friction in supply main to Bangalore at 6′ per mile	33
Total head to pump against ...	356 feet.

24. It was specified that the pumps should be able to throw up a week's supply in six days of twelve hours, or at the rate of 66,540 gallons per hour.

25. For this work Messrs. Richardson and Cruddas recommend three sets of engines, pumps and boilers, any two of which working together shall work up to the required quantity, leaving a third (engine, pumps and boiler) in reserve.

26. They recommend direct acting, compound condensing engines and pumps.

High pressure steam cylinder	21 inches diameter,
Low pressure	36 „
Pumps 48 inches stroke	12 „ diameter, and
Lancashire boilers each of 35 H.P. nominal.	

Their estimate for three sets of the above delivered in Bangalore is Rs. 53,000.

27. An idea of the combined pump and engine can be obtained from the woodcut at page 35 of Messrs. Richardson and Cruddas' catalogue. The woodcut, however, does not represent a compound engine. It is extremely compact, each pump and engine only occupying a space of 28′ × 3½′, so the three pumps can be arranged alongside in a room measuring about 48′ × 35′. These pumps are made for lifts from 250 to 1,500 feet for quantities of water from 3,000 to 50,000 gallons per hour.

28. A provision of Rs. 12,000 has been made for engine and boiler houses. A detailed estimate has not been made out, as one amounting to Rs. 9,260, based on very liberal rates, was framed in connection with the Agram tank scheme; rather more accommodation will be required in this instance, for which the extra Rs. 2,940 will be sufficient provision.

29. The Agram tank scheme estimate for quarters, Rs. 14,000, has also been adopted; provision is made therein for quarters for one European Engineer and two European or Eurasian drivers, for native stokers, and for a store-room and office, the whole surrounded by a wall, &c. At Mágadi road (Maligal) a good site for the quarters will be on the hill-top above the right end of the dam.

30. As in Maligal reservoir with one year's supply stored there will be 31½ feet difference of level between highest and lowest water-levels, and as pumps cannot be placed more than about 25 feet above the lowest level to be pumped from to avoid the necessity of placing the pumps below engine level, it has been decided to place the pumps in rear of the dam; the site marked on the survey will be a suitable one. Although perhaps not so safe as if placed above the dam and above M.W.L., the arrangement admits of the cheaper and more compact form of engine described.

Site for engines and pumps.

31. To store one year's supply a dam 45 feet above present bed of stream at the proposed site will be required. At the centre section a height of 50½ feet has been allowed for; the cross section of the valley at site shows the various levels of foundations proposed; they are probably lower than will be found necessary.

Dam of masonry and concrete.

32. The site selected is a little higher up the stream than that intended by Mr. Lee. At the latter, the line of strike of the rocks, with all the joints and fissures, are parallel to the axis of the stream, while higher up the line of strike is perpendicular to the river, and the bed of rock is much harder and sounder as far as can be judged by gullies, trial pits and other indications. This bed of rock extends all over the valley at no great depth.

33. Taking the Bhim Tal dam near Naini Tal as a precedent, it is proposed to form this dam of two outer skins or walls of coursed rubble in cement mortar, thus obviating the necessity for supporting planking when carrying up the concrete hearting of the dam. It was intended to use Portland cement for the entire mass of concrete, but the Chief Engineer being of opinion that an outer casing of cement concrete would be sufficient, the estimate has been framed accordingly, allowing for the rubble casing in front and rear, and a thickness of 2 feet of the concrete in rear of the front rubble face to be in cement mortar. The remainder of the concrete to be of ordinary lime mortar. The additional cost of the dam, laying all the concrete in cement, would be Rs. 77,353.* Probably a lighter section than has been estimated for near the flanks would suffice.

*3,223 at Rs. 24, the difference of rates for cement and lime concrete.

34. A diagram showing the section of the dam with the curves of pressure, and a table of weights and pressures and also the required dimensions if calculated by Molesworth's formula, accompanies the estimates.

35. After some consideration the right end of the dam was fixed on as the best site for a surplus weir; there is evidently a bed of rock at no great depth below the surface; a trial pit shows rock at level 55·0. The weir has been designed for a drop, still 5 feet lower, of a type which has been found to answer well and is much less expensive than a clear drop.

Surplus arrangements.

36. As designed, the 150 feet of weir with a depth of 3 feet passing over will discharge half an inch of rain per hour from the catchment of 9 square miles.

37. According to Mysore Public Works Department experience, as much as 1 inch per hour from a catchment of this area and description may occasionally be expected; but to provide a weir for so exceptional occasions seems unnecessary, as an arrangement might be made to pass such excessive rain fall over the dam. The staff in charge of the pumping machinery could easily look after and work any simple arrangement decided on. Water so surplussing will fall on the rear slope of the dam up to depth over crest of 3 feet.

38. As shown on the reservoir survey, the weir bye-wash bed is placed at + 50 and carried along till this level runs out of cutting, where the surplus can be passed over the rock into an existing ravine. It is believed, however, that a rocky bed will be met with above this level (*i.e.*, + 50).

39. The left embankment of the bye-wash can be formed from the cutting; provision is made for a substantial, grouted and pointed revetment to it for a length of 400 feet below the weir rear wings.

40. The pump valves will be placed at level 58·48, or 25 feet above the lowest take-off level in the reservoir; from the pumps the supply main to Bangalore will be carried round the left side of the reservoir for a short distance and thence strike away in a north-easterly direction, crossing the road from Bangalore to Mágadi near furlong stone ¼; thence the line will run, with three slight bends, to the Mantapum hill, where it is proposed to place settling ponds, filters and service reservoir.

Supply main to Bangalore.

41. The line will not pass near the pettah, and in selecting it (the line) the objects kept in view were to secure the shortest route, subject to facilities of laying and the avoidance of sudden rises and dips; two or three small ravines will have to be crossed, for which a lump sum provision has been made in the estimate; the cheapest arrangement will be to support the pipes on the roughstone posts so universally used, or on light bridges formed of old rails. The line crosses the Mysore State Railway to Tumkur about a mile north of the Pettah terminus.

42. As the pipes nearest to the reservoir have the heaviest head to withstand, a heavier section of metal has been allowed, 1″ in thickness for the first mile, 1/16″ for the next, and ⅞″ for all the rest. For practical reasons the pipes cannot well be of less thickness than ⅞″. A sufficient number of scour cocks, air and back or reflux pressure valves have been allowed for. All the items and rates have been carefully considered.

43. As noted in para. 23, the size of the main has been calculated (as also for the other schemes) taking a head of 6 feet per mile, the week's supply being pumped up in 6 days of 12 hours $\frac{770{,}000 \text{ cubic feet}}{72 \text{ hours} \times 60 \times 60} =$ 2·96, say 3 cubic feet, required discharge per second. An 18″ pipe by Kutter's formula will at 6′ per mile discharge rather more, or 3·4 C.′ per 1″. However a 17″ pipe would be too small, discharge 2·86 feet per 1″; so the larger size has been adopted.

Size of supply main.

Messrs. Richardson and Cruddas, in connection with the engines, considered the size 18″ as specified suitable.

44. It is proposed to construct these on the Mantapum hill. The only disadvantage of this site is that it necessitates about a mile extra of supply pipe to the cantonment, but there are several counterbalancing advantages.

Settling pond, filters and service reservoir.

(*a*) The site is at the highest available level.

(*b*) It is well away from all dwellings and their accompanying sources of contamination.

(*c*) The land can easily be made available and no existing rights of any consequence will be interfered with.

(*d*) The only other suitable sites are either the golf ground or the high ground; for the former floor of service reservoir should be placed at level 3,030, for the latter 3,040, thus reducing the head for distribution, and neither site affords the same facilities for construction, and they are besides much used as recreation grounds by the officers of the garrison and other European residents. The constructions in question would completely spoil either.

(*e*) The site selected on the slope of the hill admits of the settling ponds, filters and service reservoir being arranged at suitable levels with reference to one another (*vide* plan No. 14).

(*f*) For either Hebbal or Nagavaram schemes the one disadvantage noted disappears.

30. As in Maligal reservoir with one year's supply stored there will be 31½ feet difference of level between highest and lowest water-levels, and as pumps cannot be placed more than about 25 feet above the lowest level to be pumped from to avoid the necessity of placing the pumps below engine level, it has been decided to place the pumps in rear of the dam; the site marked on the survey will be a suitable one. Although perhaps not so safe as if placed above the dam and above M.W.L., the arrangement admits of the cheaper and more compact form of engine described.

Site for engines and pumps.

31. To store one year's supply a dam 45 feet above present bed of stream at the proposed site will be required. At the centre section a height of 50½ feet has been allowed for; the cross section of the valley at site shows the various levels of foundations proposed; they are probably lower than will be found necessary.

Dam of masonry and concrete.

32. The site selected is a little higher up the stream than that intended by Mr. Lee. At the latter, the line of strike of the rocks, with all the joints and fissures, are parallel to the axis of the stream, while higher up the line of strike is perpendicular to the river, and the bed of rock is much harder and sounder as far as can be judged by gullies, trial pits and other indications. This bed of rock extends all over the valley at no great depth.

33. Taking the Bhim Tal dam near Naini Tal as a precedent, it is proposed to form this dam of two outer skins or walls of coursed rubble in cement mortar, thus obviating the necessity for supporting planking when carrying up the concrete concrete, but the Chief Engineer being of opinion that an outer casing of cement concrete would be sufficient, the estimate has been framed accordingly, allowing for the rubble casing in front and rear, and a thickness of 2 feet of the concrete in rear of the front rubble face to be in cement mortar. The remainder of the concrete to be of ordinary lime mortar. The additional cost of the dam, laying all the concrete in cement, would be Rs. 77,353.* Probably a lighter section than has been estimated for near the flanks would suffice.

*3,223 at Rs. 24, the difference of rates for cement and lime concrete.

34. A diagram showing the section of the dam with the curves of pressure, and a table of weights and pressures and also the required dimensions if calculated by Molesworth's formula, accompanies the estimates.

35. After some consideration the right end of the dam was fixed on as the best site for a surplus weir; there is evidently a bed of rock at no great depth below the surface; a trial pit shows rock at level 55·0. The weir has been designed for a drop, still 5 feet lower, of a type which has been found to answer well and is much less expensive than a clear drop.

Surplus arrangements.

36. As designed, the 150 feet of weir with a depth of 3 feet passing over will discharge half an inch of rain per hour from the catchment of 9 square miles.

37. According to Mysore Public Works Department experience, as much as 1 inch per hour from a catchment of this area and description may occasionally be expected; but to provide a weir for so exceptional occasions seems unnecessary, as an arrangement might be made to pass such excessive rain fall over the dam. The staff in charge of the pumping machinery could easily look after and work any simple arrangement decided on. Water so surplussing will fall on the rear slope of the dam up to depth over crest of 3 feet.

38. As shown on the reservoir survey, the weir bye-wash bed is placed at + 50 and carried along till this level runs out of cutting, where the surplus can be passed over the rock into an existing ravine. It is believed, however, that a rocky bed will be met with above this level (*i.e.*, + 50).

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Supply main to Bangalore.

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42. As the pipes nearest to the reservoir have the heaviest head to withstand, a heavier section of metal has been allowed, 1″ in thickness for the first mile, 13/16″ for the next, and ¾″ for all the rest. For practical reasons the pipes cannot well be of less thickness than ¾″. A sufficient number of scour cocks, air and back or reflux pressure valves have been allowed for. All the items and rates have been carefully considered.

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43. As noted in para. 23, the size of the main has been calculated (as also for the other schemes) taking a head of 6 feet per mile, the week's supply being pumped up in 6 days of 12 hours $\frac{770{,}000 \text{ cubic feet}}{72 \text{ hours} \times 60 \times 60} =$ 2·96, say 3 cubic feet, required discharge per second. An 18″ pipe by Kutter's formula will at 6′ per mile discharge rather more, or 3·4 C.′ per 1″. However a 17″ pipe would be too small, discharge 2·86 feet per 1″; so the larger size has been adopted.

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(*e*) The site selected on the slope of the hill admits of the settling ponds, filters and service reservoir being arranged at suitable levels with reference to one another (*vide* plan No. 14).

(*f*) For either Hebbal or Nagavaram schemes the one disadvantage noted disappears.

(*g*) Borings to a depth, lower than necessary for excavation, show the soil to be pretty similar to that visible on the surface, *i.e.*, hard compact lateritic soil; mixed with water the clay from the borings seemed almost fit for puddle, so that there can be no objection to constructing ponds, filters and service reservoir as proposed, *i.e.*, in cutting, with a good facing of cement concrete laid on the slopes, cut into steps, if constructed with masonry sides, the works would be considerably more expensive.

45. The question of placing these works near the supply reservoir has been considered and the idea abandoned as it would involve additional pumping, as there is no suitable site below the reservoir where they could economically be constructed. The pumps proposed are specially adapted to the pumping of muddy water.

The plan shows the general arrangements.

46. The settling ponds have been designed for a depth of 8 feet of water, of which 7 feet can be drawn off leaving 1 foot of depth for silt accumulation, each pond to hold one day's supply. It will be a question for future consideration if a greater number of ponds should not be provided. With a view to deliver the water into the ponds as quietly as possible, the supply main from the pumps will deliver into a large circular well, whence the water will be conveyed by iron pipes, regulated by valves, to masonry chambers, and thence by overfalls which can be regulated by shutters, into the ponds.

Details.

47. From the ponds the water will be drawn off by means of adjustable (or floating) suction pipes, which the drawings will fully explain, into the filters.

48. Two have been provided for, each capable of filtering a day's supply in 24 hours, at the rate of 50 gallons per square foot per 24 hours. A liberal allowance as 75 gallons is commonly taken as the duty of a filter. The draw-off sluices from the filters to the service reservoir are arranged so that the necessary head on the filters can be arranged to any required extent, from 1 inch up to 3 feet; probably 18″ will be found sufficient; the arrangements for turning the water from either settling pond to either filter are shown on the plan.

Filters.

49. Designed to contain rather more than three days' supply. With a view to keeping the water as cool as possible, a roof formed by a series of flat-brick arches has been provided. It is now generally admitted that service reservoirs should be so covered in. The roughstone pillars allowed for are universally used in Mysore and they are cheaper, cleaner and occupy less space than brick arches would. Rolled iron beams have been allowed for, but old railway rails would do equally well and would probably be cheaper.

Service reservoir.

50. Town distribution will now be described when the Mágadi road scheme will as a whole have been considered.

The remarks regarding the settling ponds, filters, service reservoir and distribution will be common to the other two schemes for the supply to cantonment and garrison, so there will be no need to recapitulate them.

51. The distance fixed, 600 feet, in a straight line, nearer than which water need not be brought to any house, greatly simplifies the system.

The proposed lines of piping are shown on the accompanying two sheets of the Topographical Survey of the cantonment, and the statement of distribution details gives particulars of the various lines proposed.

52. The original intention was to have worked out the system in greater detail, by taking careful measurements and levels for each line, as also by the preparation of detailed drawings and estimates for each special curve and connection required (as was done for the Ootacamund distribution). But under recent instructions it was not possible to do all this, so the estimate is based on the survey; some

of the lines have been levelled and many of the survey B.Ms. checked, and, with one exception, the latter have been found to agree well with recently taken levels; some differences have also been found between the levels of the troop supply cisterns.

53. All the levels connected with the various schemes are taken from B. M. No. 2 at the N. E. corner of the golf ground opposite this office (No. 6 Bellary road) gateway; this B. M. was recently moved, but has been again put in at the same level as that given for it on the Topographical Survey 3057·48 M.S.L. A connecting level to the S. W. corner of the office plinth gives a value to the latter of 3056·83. A list of the levels of various other points which have been levelled to accompanies.

54. For purposes of calculation the population has been taken—Europeans 5,000, natives 100,000; this latter figure is probably 6,000 over the actual at present, but the allowance of 6,000 for increase is not excessive. It has been decided * to allow two cubic feet per day for Europeans and one cubic foot for natives. To properly proportion the pipes statements of the population, street by street, would be required, but no such information is available in the Municipal office; all that could be obtained was a statement of areas and population, and even this is very incomplete and does not include the whole of the population; however it has been used to some extent and partly by guess the population has been divided amongst the various lines as shown in the distribution statement, and the sizes of the pipes thus deduced seem reasonable enough and are capable of distributing the required quantities in eight hours.

* Reference No. 3.

55. The statement of distribution fittings gives the particulars of the various fittings allowed for each line. The European Infantry barrack cistern will be supplied by No. 2 branch of main line No. 4. This latter line will at its termination near Trinity Church join the existing supply pipes to the Cavalry and Artillery barracks.

56. Probably here and there short lengths of extra piping will be required to bring certain localities within the limit of distance, but there is ample provision in the estimate for such contingencies.

57. The rates allowed for actual pipe-laying are much lower than were allowed at Ootacamund, but they are believed to be sufficient, each item, lead, yarn and excavation have been separately allowed for.

58. Of the two lines for the main from the reservoir to the bifurcation of the distribution mains, the alternative line to the west is some 700 feet shorter and will probably be preferable; the estimate has been made out for the other, but no great difference would result, as though the grade would be increased from $\frac{1}{1000}$ to $\frac{1}{1100}$ the discharge of the pipe would not be materially increased, and so its size 15½″ could not well be reduced.

59. From the comparative statement of cost and other particulars this scheme would at first sight seem most promising. The tank also is well calculated to attract popular attention, situated as it is on the high road to Bellary at no great distance from the station and at a higher level than any of the other sources of supply, a fine looking sheet of water, of 204 acres in extent, at present weir level.

Hebbal tank scheme.

60. The total catchment area is 13 square miles, of which only 5 square miles are free, as marked by a dark green line on the map, and in considering these schemes it has been decided that only *free* catchment can safely be counted on, and in connection with the run-off, even from free catchment, the remarks in paragraph 15 should not be lost sight of.

61. The catchment can hardly be considered a steep one, and in the middle it is very flat.

62. The tables of capacity and areas and the table of consumption and waste show that to store one year's supply (40 M. C. feet) it is necessary to impound 123 M. C. feet, so that 83 M. C. feet

Supply required.

would be wasted and lost in evaporation owing to the great water-spread of the tank, which at the level, (7½ feet above weir) required to store 123 M. C. feet is some 361 acres in extent.

Supply available.

63. It only remains to apply the data of run-off, per square mile, of free catchment—

Miles.
5× 7 = 35 M. C. feet available in a bad season.
5×11 = 55 M. C. in an average season.
5×17 = 85 Maximum supply.

64. In a year, however, of average fall, with the character of the rainfall at all favorable, there can be little doubt that the required quantity could be impounded, as then the run off from the entire catchment of 13 square miles could be counted on. During the progress of these investigations the tank has surplused several times, but if it be decided, as is believed, to be absolutely necessary, that at least 18 months' supply should be stored, over 200 M. C. feet would be required, involving the raising of the tank about 20 feet and the submerging * of a large area of valuable land.

* *Vide* contour survey of tank.

65. These do not seem to call for particular notice, the tank bund carries the Bellary road, hence the necessity for the top width allowed. The present weir is crossed by a bridge of 7 vents of 9 feet

Estimates.

replacing the arches with rolled iron beams and buckled plates, and raising the body wall in rear of the bridge as shown on the sections.

66. The nature of soil in rear of bund is shown on the bore hole diagram.

67. The distance of the tank from the filters and service reservoir being so much less than Mágadi road reduces the cost of the supply main, and this shorter distance and smaller lift materially reduces the first cost of the engines and the working expenses. The same establishment would however, it is considered, be necessary as for the more powerful engines required at Mágadi road.

68. This tank is in the same valley as the Hebbal, about 1¼ miles lower down to the east. The weir is 23 feet lower than that of Hebbal. Correctly speaking, its free catchment is only 3·6 square miles, its total catchment being Hebbal catchment of 13 square miles + 3·6 = 16·6 square miles to obtain the 8½ miles of free catchment alluded to in G.O., No. 25 W., of 8th January 1889; the 5 square miles of Hebbal free catchment must be reckoned on.

Nagavara tank scheme.

Major Kensington proposed to increase the catchment and take up the surplus of Jukkur tank by a catch channel, but the unfavorable opinion reported regarding a work of the kind has been endorsed by the Chief Engineer, so the proposal has not been carried further; indeed the Mysore experience of catch channels is not encouraging, and in this instance, as the tank should be raised 11½ feet, the fall available from the Jukkur tank would not then be sufficient.

69. The tables of capacity and consumption show that for a year's supply (40 M. C. feet) 106 M. C. feet must be impounded, and to do this weir level must be raised 11½ feet, the water-spread being increased from 86 to 334 acres, the land which would be submerged is valuable, being under wet and garden cultivation. The comparative statement gives (as also for the other schemes) the approximate cost of compensation, and if for this scheme the Hebbal tank were deprived of the water from the five square miles of *its* free catchment, it would happen that in bad years the Hebbal tank could not supply the land irrigated by it; hence in both estimates appears the same sum Rs. 10,770 compensation for land deprived of water.

Supply required, &c.

70. Applying the data as in para. 63—

Supply available.

Miles.
8·5× 7=59·5 M. C. feet minimum.
8·5×11=93·5 M. C. F. in an average season.
8·5×17=144·5 M. C. F. maximum against 106 M. C. F. required.

As in the case of Hebbal tank (para. 64) in an average year a supply from the total catchment might be counted on.

71. To impound 1½ year's supply, though the area submerged, while it would not be so great as at Hebbal, would involve the acquisition of much valuable land.

72. The estimates seem to call for no remark, as they have been prepared on the same lines as the others. The bore hole diagram gives the results of two borings made below the bund.

73. The catchment areas of both Hebbal and Nagavara tanks cannot by any means be considered clean; they are both highly cultivated, and being close to Bangalore receive a considerable amount of night-soil manure; parts of the Nagavara catchment are most offensive. Neither catchment can be nearly so clean as that of the Hessargatta tank, which has been condemned as a source of supply partly for this reason.*

Impurity of catchment areas.

* Reference No. 4.

74. As shown, both Hebbal and Nagavara tanks fail when reviewed in the light of the data available. So, as has been reported, the only cheap alternative to the Mágadi road scheme would be the Rachanhalli (or Dhasarhalli) tank; this is at the same level as the Nagavara tank, and only ¾ mile further out to the north. It is in a narrower and deeper valley than the Nagavara and so the water-spread would be smaller, and to store a year's supply it need only be raised about 8 feet. Its total catchment is 36 square miles, of which 15 square miles may be considered free, as the tanks in this area are shallow and unimportant; and the chief one, the Jukkur, irrigates but a small area. A more detailed report and approximate estimate for a supply from this source will shortly follow.

Rachanhalli.

75. To briefly summarize for the three schemes which have been worked out for the supply of the cantonment and garrison:—

Summary.

MAGADI ROAD.

Pros.

Most advantageous catchment basin, valley steep and narrow, insuring a rapid and high percentage of run-off, the whole catchment being free.

2. Catchment now only cultivated to a small extent, and that with crops but slightly manured.

3. Advantageous site for the formation of the supply reservoir, a deep narrow valley, height of dam to store one year's supply 45 feet above river-bed, area of water-spread at that level 85 acres. Height of dam to store 18 months' supply 54½ feet, area of water-spread at that level 124 acres. A still larger supply could be stored if necessary.

4. Analysis shows the quality of the water from this source to be much purer than any of the others.

5. Constantly flowing stream of limpid water flow, said to continue even in the driest weather to a small extent.

Cons.

1. Cost of the project and annual working charges.

2. Possible difficulties with the reservoir owing to the amount of silt brought down by floods.

3. *Possible* difficulties in obtaining permission from the Mysore Government to carry out the works as the supply of the Pettah from this source has been talked of; however there should not be great difficulty from this cause as Sankey's tank has been handed over to Mysore.

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76. HEBBAL AND NAGAVARA SCHEMES.

Pros.

Smaller initial cost with lower annual cost for working. Distance to sources of supply being less as also heads to be pumped against. These advantages are also in favor of the Hebbal scheme as compared with Nagavara, while there is but little counterbalancing advantage in favor of the latter, as here the compensation for land submerged would be much more costly. The latter tank is now rapidly drying up. Rather than reserve the 5 square miles of free catchment belonging to Hebbal to supply the Nagavara tank for supply of the town, it would be better to adopt the Hebbal tank as a source of supply and increase its free catchment by taking up some of the tanks above it.

Cons.

1. Water not so pure as that of Mágadi road.
2. Shallow tanks of great water-spread involving the storage of a large volume of water to meet loss by evaporation and leakage.
3. Catchment basins not large enough to furnish required supplies in any but favorable seasons of rainfall.
4. Catchment basins highly cultivated and manured and generally not favorable to a rapid run off.
5. Cost of compensation for land submerged and deprived of water would be expensive, as land in both localities is valuable.

77. *General Summary.*—All in favor of Mágadi road. To reserve the free catchment areas would be very expensive. The cost has not been brought into the estimate for each scheme, but has been added, at foot, in the general abstract. The amount for Mágadi road has been made out in detail by the Mysore Revenue Department, for the other schemes approximate values deduced from total areas and average value of the land have been entered.

78. A statement accompanies showing how the annual working charges have been arrived at. As in previous estimates 15 per cent. interest and depreciation has been allowed on the machinery, but only 7 per cent. on all other iron-work, pipes and fittings, &c., and 4 per cent. on the balances of the estimates. The entries for establishment should suffice, and in making them out the cost of working the elaborate engines which drive the cotton spinning mills at this place has been looked into. These are worked very inexpensively by a far smaller establishment than had now been allowed for, but even this latter is only about half of the present Ulsur establishment, where also the cost of firewood is greater than at the cotton mills, the reason assigned being that the mills are at liberty to make advances to contractors which a Government department cannot do. At Ulsur works wood fuel has been costing from 217 lb. to 270 lb. per Re. 1. At the cotton mills, Re. 1 per 316 lb. 300 lb. per rupee has been taken as the cost for these calculations, the consumption of wood per hour has been taken as quoted by Messrs. Richardson and Cruddas for each engine. Of course the comparatively antiquated engines and pumps of the Ulsur works could not be as economically managed as the more perfect machines now in the market.

Cost of working.

And in considering the cost of working the schemes under reference, the cost of the present Ulsur supply for the troops alone (Rs. 16,565 for establishment and working *plus* allowance for interest on first cost, this latter has been calculated to amount to Rs. 31,889, total Rs. 48,454*) should be deducted, it represents almost an annual dead loss to Government. If a combined supply to garrison and cantonment were carried out, the annual total cost could easily be met by a very low water-rate, about Re. 1 per head of the population, who already probably pay as much or more for their present unsatisfactory supply. As far as has been ascertained a water-rate would be cheerfully paid.

* Cost for 1,000 gallons Rs. 2¼.

SUPPLY SCHEME FOR THE GARRISON ALONE.

The importance and urgency of obtaining a pure and unfailing supply of water for the garrison, in the event of its not being found possible to carry out a supply scheme for the garrison and cantonment combined, being recognized, the estimates, amounting to Rs. 2,34,130, have been prepared; the comparative statement gives the cost and other particulars side by side

Reference No. 4.

with the large schemes. The annual working expenses are estimated at Rs. 20,000, cost per 1,000 gallons being Rs. 0-14-0 against Rs. 2½ per 1,000 gallons, cost of the existing Ulsur supply.

2. It is proposed to draw the supply from the same source, as for the combined supply from Mágadi road, only in this case a smaller catchment area being required, a point has been selected ¾ of a mile *above* the bridge over the stream at 5¾ miles of the road from Bangalore to Mágadi. Above this point the catchment area is 5 square miles, as colored by a pink line of deeper tint on the Topographical Survey.

3. Taking as laid down the required supply at 10,000* cubic feet per day the tables of capacity and consumption show (evaporation and waste as before, 0·7 feet per month) that for the year's supply of 3·65 M. C. feet 8 M. C. feet must be stored in the reservoir, the height of dam required being 28 feet above river-bed.

Reference No. 4.

4. The dam is colored pink on the cross section of the valley, the section of the dam for so much of the height from the top to be the same as designed for the large reservoir. The estimate provides for cement right through as it is proposed to surplus over the dam, provision being made for a mass of rough stone in rear.

5. For the reasons set forth in paras. 12 to 18 of the report on the combined supply, it is thought that 18 months' supply should here also be stored, also that a supply for the native troops in garrison should be included. The supply of 10,000 cubic feet per day is based on the requirements of the European troops; only a slight addition to the height of the dam would be needed, the engine power and main provided for is capable of pumping up a larger supply.

6. Provision is made for two sets of direct acting compound engines, pumps and boilers, either of them capable of pumping up a week's supply in three days of ten hours through a 10-inch main.

Engines and pumps.

7. The size of the main has been calculated as before, a head of 6 feet per mile being allowed, seven days' supply pumped up in three days of ten hours, *i.e.*, $\frac{70,000}{3 \times 10 \times 60 \times 60} = 0{\cdot}648$ cubic feet per second, a quantity the 10-inch pipe will discharge.

8. The same arrangement of settling ponds, filters and service reservoir as for the larger schemes has been estimated for, the service reservoir to hold ten days' supply and to be roofed in with brick arches supported by stone pillars and rolled iron beams similar to the one proposed for the larger schemes.

Settling ponds, filters and service reservoir.

A suitable site will be on the South Parade as shown on the Topographical Survey of the cantonment. Borings show the soil to be a firm red clay with some sand. From the service reservoir the supply can be conveyed to the Infantry barracks cistern and on by the existing lines of pipe to the Cavalry and Artillery cisterns.

(*a*) In drawing up this report endeavours have been made to make it as concise as possible, consequently nothing has been noted regarding topographical peculiarities of the country, climate, rainfall, &c.; quite enough has already been written on these subjects.

Concluding remarks.

Chapter II of Mr. Lee's essay contains a general description of Bangalore, and in the same pamphlet is a diagram showing the rainfall for a series of years. The levels given in the pamphlet are incorrect and the estimates extremely sketchy, and with reference to the notification published with G.O., No. 2810 W. of 20th October 1887 (page iii of Mr. Lee's essay), it may be noted that the essay has not in any way been adopted as the foundation of the Mágadi road scheme as now prepared except so far as indicating the locality and source of supply.

* Over 11,000 cubic feet per diem have been pumped up from Ulsur in the dry season.

(*b*) All the estimates which have hitherto been prepared for the water-supply of Bangalore made provision for stand-pipes, an obsolete expedient now hardly ever adopted, the necessary pressure to force the water through the mains is now-a-days always communicated by the engine through the medium of an air vessel.

(*c*) For the sake of comparison a table is appended, giving the estimated amounts of the garrison supply estimate as now prepared and that drawn up by the late Captain Romilly for a garrison supply from the Agram tank.

(*d*) The projects as now submitted are by no means as complete, particularly as regards plans as the undersigned could have wished; but as time was an object, most of the plans are sent just as they have been roughly drawn out in pencil.

(*e*) The Hessargatta tank on the Arkavati river has been brought forward as a source of supply by Colonel Vibart and has been briefly alluded to in para. 73. It is thought that the objection to the impurity of the catchment is not a very serious one; the table of analysis shows the water to be good. There can be no question that a very large volume of water could be impounded in an ordinary year, as per figures given in this office report No. 74 of 26th November 1888. Notwithstanding the greater distance—11 miles from service reservoir site—the level of the tank being higher, the head to be pumped against would be 18 feet less than at Mágadi road. To impound a two years' supply the cost would not probably be much more than at Mágadi road, and at the latter locality would be the risk and chances of leakage attending the construction of a high dam. At Hessargatta the existing tank of a capacity of 91 M.C. feet with its massive old bund would be, as it were, a reliable foundation to start from.

J. C. LARMINIE,
Executive Engineer.

2nd February 1889.

BANGALORE WATER-SUPPLY.

* COMPARATIVE Statement showing cost and other particulars, &c., of the various schemes proposed.

—	Nágavara.	Garrison supply.	Mágadi Road Maligal.	Hebbal Tank.
Distance from source of supply to service reservoir.	3	11 miles.	5 miles.	2¼
Head to be pumped against	186	232 feet.	356	162
Lowest take-off level	2897·0	2703·27	2741·71	2918·0
Delivery level in settling ponds ..	3090·0	3014·62	3090·0	3090·0
Areas of reservoirs at F. S. L. ..	314·6 acres.	18·22	84·76 acres.	361
	106 M. C. feet	8·324		
Capacities of do. at do.	13·6	5	60·54	123·4
Total catchment area	3·5	5	9	13
Free do. do.			9	5·0
			Abstract of Estimates.	
Dam	30,500	50,000	1,92,740	25,650
Engines, pumps and boilers	44,000	13,000	63,000	40,000
Connection with reservoir			1,000	
Pump well	1,500	4,000	1,500	1,500
Engine and boiler-house	12,000	6,000	12,000	12,000
Chimney	3,000	2,000	5,000	3,000
Quarters for establishment	14,000	6,000	14,000	14,000
Supply main	1,51,900	1,12,500	2,57,000	1,15,400
Settling ponds	37,350	14,310	37,350	37,350
Filters	36,860	7,610	36,860	36,860
Service reservoir	63,430	21,510	63,430	63,430
Town distribution	2,29,744	18 acres at Rs. 50.	2,29,744	2,29,744
	200 acres at Rs. 100.		85 acres at Rs. 100.	100 acres at Rs. 100.
Compensation for land submerged by reservoir ..	60 ,, at ,, 300.	900	8,500	57 ,, at ,, 150.
	10,770	..	..	18,550
Do. for land deprived of water				Assessment × 10.
				10,770
Total ..	6,86,054	2,34,130	9,02,124	6,98,254
Annual cost of working	* 65,599	* 20,000	* 91,000	* 61,000
Cost of water per 1,000 gallons	Rs. 0 4 3	Rs. 0 1 4 0	Rs. 0 6 9	Rs. 0 3 3

* Including interest on cost of construction.

J. C. LARMINIE,
Executive Engineer.

SUPPLEMENTAL REPORT by J. C. LARMINIE, Esq., dated 18th February 1889.

BANGALORE WATER SUPPLY.

Supplemental Report on the proposal to supply the Garrison and Cantonment from the Rachanhalli (or Dasaralli Tank).

The report which has been already submitted treats of the question of obtaining a supply from three sources—

Reference.

Para. 74 of report which accompanies the estimates which have been already submitted.

1st—Mágadi Road.
2nd—Hebbal Tank.
3rd—Nagavara Tank.

The first named is likely to prove an expensive scheme, both for first construction and subsequent working, and is not besides without its drawbacks, the chief being the uncertainty attendant on the construction of a new masonry dam.

2. The two latter schemes completely fail when considered in the light of the data decided on, chiefly owing to the small areas of free catchments available; consequently a source of supply which, while combining the advantages of the two latter schemes, *i.e.*, comparatively high level and proximity to Bangalore, with a larger catchment area, would comply with the necessary requirements. The Rachanhalli tank fulfils these conditions fairly well.

3. It is just ¾ of a mile further out, to the north, than the Nagavara tank and almost at the same level; the accompanying comparative statement compares its particulars with those of the three schemes for the combined supply as already submitted.

4. The conditions of the catchment basin are more favorable than those of either Hebbal or Nagavara tanks.

(*a*) As to the total area, *i.e.*, 36 square miles, and here it may be remarked that under the conditions of rainfall prevailing in Mysore a large catchment, though even not free, is of value, as the chances then of catching local showers are so much better. Major Kensington, R.E., who has had considerable experience of Mysore, considers that, by far the best tank filling rains, are not those of the monsoons, but the local showers that fall before and after each monsoon; this quite agrees with the experience (limited of course) gained during these investigations, and it is from these very local showers, which usually come down in sudden heavy bursts of short duration, that the greatest percentage of run-off is obtained.

(*b*) The catchment is not so highly cultivated, and being further from Bangalore and more out of the way, receives but little (if any) of the clearances from the dust-bins. The good quality of the water is shown by the table of analysis.

(*c*) The catchment is steeper and narrower, and observation after heavy rain showed a rapid and copious run-off.

(*d*) The catchment of 15 square miles, which may be considered free, is colored burnt sienna on the 1 inch Topographical sheets which accompany the first report.

5. It is true that several tanks appear in this area, but the principal one, the Jukkur, would disappear, as its ayacut would be submerged by the raising of water level in the Rachanhalli tank, so under the head land compensation provision is made for taking up this area (only 87 acres). All the other tanks are shallow ponds of no importance.

6. The remaining 21 square miles of the total catchment extend away to the north of Yelahanka as marked by a blue pencil dotted line on the map. The Yelahanka is a considerable tank, which at times passes off much surplus.

7. The table of consumption shows that to store a year's supply, present full tank level must be raised 7¾ feet, when the three tanks will compare as under.

—	Hebbal.	Nagavara.	Rachanhalli.
Extra depth required to store one year's supply	feet 7¼	11¼	7¾
Area of water-spread when so raised	acres 361	334	338
Corresponding capacity	„ 123·4	106	118

8. It has been already shown that of the two tanks, Hebbal and Nagavara, the balance of advantages is rather in favor of Hebbal, so only with this latter tank need further comparison be drawn.

9. For one year's supply the area of water-spread and required capacity are smaller at Rachanhalli, as shown by the statement (of particulars and cost); the amount of compensation for land submerged by the reservoir is Rs. 1,300 more at Rachanhalli, but it is believed that the former (Hebbal) is under-estimated and that more *wet* land would be submerged than is allowed for. There was no time to obtain exact particulars like those now given for Rachanhalli tank, while as a set-off against the land submerged in this case would be the land obtainable around the margin of the Jukkur tank, the weir of which might be lowered 6 feet, and as the tank would be no longer required for irrigation (*vide* para. 5), the stone now forming its revetment could be utilized for the Rachanhalli tank, and accordingly a lower rate for revetment has been allowed in the estimate for the latter.

10. But it is in the comparison of the run-off on the catchment area of Rachanhalli with that from Hebbal and Nagavara areas as compared with the required amount of water that the advantages of the former scheme become most apparent.

—	Hebbal.	Nagavara.	Rachanhalli.
	M.C.F.	M.C.F	M.C.F.
Required for one year's supply ...	123	106	118
Available, *i.e.*, free	5×7	3·6×7	15×7
Catchment × 7 M.C.F.	35	25·2	105
Deficiency ...	88	80·8	13

11. But if it be admitted that it will not do to trust to obtaining invariably a minimum of 7 M. C. F. run-off, and that at least 18 months' must be stored, which in an ordinary year can easily be done, then the Rachanhalli tank has still further advantages over Hebbal for storing the greater supply, for, as the contoured survey of the tank shows, a further rise of level of the water would only submerge an inconsiderable area along the right and left margins; 18 months' supply could not be stored at Hebbal without submerging a large area of valuable land, raised 7¾ feet as shown, for one year's supply, the water-spread (of Rachanhalli) would then be 6 feet below the weirs of the Jukkur tank, so that this latter might be used as a supplemental reservoir to the other. It is a deep compact little tank, containing about 55 M.C. feet between weir crest and 6 feet below that level M.C.F. and is *now* only a few inches below F.S.L. notwithstanding a considerable draw off through the sluices, pointing to the existence of copious springs in the valley, as no rain worth noting has fallen since early in November.

12. If the Jukkur tank be utilized as a supplemental reservoir, the Rachanhalli tank need not be raised for any given supply to so great an extent, but the time available now will not admit of this question being worked out.

13. The quantity of water required, if stored in the Rachanhalli Tank for 18 months' supply, has however been computed and is shown in the consumption table, in one period of six months 210 M. C. F. would be required. Present tank level should be raised 13 feet (against 7¾ feet for a twelve months' supply) or to level 63 on the tank survey, colored green, and area of water-spread at that level would be 461 acres.

14. To obtain 210 M. C. F. 6 inches of rain should run-off the free catchment of 15 square miles. Much more than this would be available in ordinary years.

15. The water in the tanks in this valley is remarkably pure and clear looking (for quality see table of analysis), so the difficulties on account of silt, likely to be met with at Mágadi road, would here be avoided.

16. The tank has two weirs of 80 and 90 feet in length; these could inexpensively be raised, for which a lump sum of Rs. 5,000 is allowed in the estimate for raising the bund.

17. The item of estimate, raising the bund (*i.e.*, dam), is less costly than either Hebbal or Nagavara, the bund being much shorter.

J. C. LARMINIE,
Executive Engineer.

18th February 1889.

SUPPLEMENTAL.

BANGALORE WATER-SUPPLY.

Comparative Statement showing cost and other particulars of the various schemes proposed for a combined supply to Garrison and Cantonment.

—	Mágadi Road. Maligal.	Hébbal Tank.	Nagavara.	Rachanhalli.	
Distance from source of supply to service reservoir.	5 miles.	2¼	4	4	
Head to be pumped against ..	356	162	186	194	2 lower than Nagavara, tank being deeper.
Lowest take-off level ..	2741·71	2918·0	2897·9	2895·0	
Delivery level in settling ponds.	3090·0	3090·0	3090·0	338 acres.	For one year's supply.
Areas of reservoirs at F. S. L.	84·76 acres.	361·0	334·6 acres.	118 M.C F.	
Capacities of do. at do. ..	60·54	123·4	108 M.C. feet.	36 sq. miles.	
Total catchment area ..	9	13	16·6	15	
Free do. do. ..	9	5·0	3·6		
		Abstract of Estimates.			
Dam	1,92,740	25,650	30,500	16,000	
Engines, pumps and boilers ..	53,000	40,000	44,000	45,000	
Connection with reservoir ..	1,000	..	..	..	
Pump well	1,500	1,500	1,500	1,500	
Engine and boiler-house ..	12,000	12,000	12,000	12,000	
Chimney	5,000	3,000	3,000	3,000	
Quarters for establishment ..	14,000	14,000	14,000	14,000	
Supply main	2,57,000	1,15,400	1,51,900	1,94,400	
Settling ponds	37,350	37,350	37,350	37,350	
Filters	36,860	36,860	36,860	36,860	
Service reservoir	53,430	53,430	*53,430	53,430	
Town distribution	2,29,744	2,29,744	2,29,744	2,29,744	
Compensation for land submerged by reservoir ..	85 acres at Rs. 100 8,500	100 acres at Rs. 100 57 acres at Rs. 150 18,550 Assessment × 10	200 acres at Rs. 100 50 acres at Rs. 200 30,000	68 acres dry at Rs. 100 87 acres wet at Rs. 150 19,850 Assessment × 10	87 acres wet ayacut of Jakkur tank submerged by raising of Rachanhalli tank.
Compensation for land deprived of water.	..	10,770	10,770	13,500	
Total ..	9,02,124	5,98,254	6,55,054	6,76,634	
Annual cost of working ..	91,000	61,000	65,500	68,000	
Cost of water per 1,000 gallons ..	Rs. 0 5 9	Rs. 0 3 3	Rs. 0 4 3	Rs. 0 4 6	

12/1000

SUPPLEMENTAL.

BANGALORE WATER-SUPPLY.

COMPARATIVE STATEMENT showing cost and other particulars of the various schemes proposed for a combined supply to Garrison and Cantonment.

—	MÁGADI ROAD, MALIGAL.	HEBBAL TANK.	NAGAVARA.	RACHANHALLI SCHEME.		Remarks.
	For 12 months' supply.			Supply for 12 months.	Supply for 24 months.	
Distance from source of supply to service reservoir.	5 miles.	2¼	3	4	4	
Head to be pumped against ..	356	162	186	194	194	
Lowest take-off level ..	2,741·71	2,918·0	2,897·0	2,895·0	2,895·0	
Delivery level in settling ponds ..	3,090·0	3,000·0	3,090·0	3,000·0	3,000·0	
Areas of reservoirs at F.S.L. ..	84·76 acres.	361·0	334·0 acres.	338 acres.	965 acres.	
Capacity of do. ..	60·54	123·4	108 M.C. ft.	118 M.C. ft.	210 M.C. ft.	
Total catchment area ..	9	13	16·6	15	36 sq. miles.	
Free do. do. ..	9	5·0	3·6	15	15	
Height of bund above present weir level. ..	..	..	..	20 feet.	21½ feet.	
				Rs.	Rs.	
Dam	1,92,740	25,650	30,500	16,000	20,500	
Engines, pumps and boilers ..	53,000	40,000	44,000	45,000	46,000	
Connection with reservoir ..	1,000	..	..	..	..	
Pump well	1,500	1,500	1,500	1,500	1,500	
Engine and boiler house ..	12,000	12,000	12,000	12,000	12,000	
Chimney	5,000	3,000	3,000	3,000	3,000	
Quarters for establishment ..	14,000	14,000	14,000	14,000	14,000	
Supply main	2,57,000	1,15,400	1,51,900	1,94,400	1,94,400	
Settling ponds	37,350	37,350	37,350	37,350	37,350	
Filters	36,860	36,860	36,860	36,860	36,860	
Service reservoir	53,430	53,430	53,430	53,430	53,430	
Town distribution	2,29,744	2,29,744	2,29,744	2,29,744	2,29,744	
Compensation for land submerged by reservoir.	85 acres at Rs. 100.	100 acres at Rs. 100. 57 ,, at ,, 150.	200 acres at Rs. 100. 50 ,, at ,, 200.	315 Rachanhalli. 245 Jakkur, at Rs. 100. 87 wet at Rs. 150.	191 acres dry at Rs. 100. 87 acres wet at Rs. 150.	87 acres wet at Jakkur.
	8,500	18,550 Assessment × 10.	30,000	69,500 *2,200	19,850 Assessment × 10.	Twice the assessment of small up-tanks.
Compensation for land deprived of water.	..	10,770	10,770	13,500	13,500	*Vide* para. 8 of addendum to report.
Total ..	9,02,124	5,98,254	6,55,054	7,64,434	7,06,634	Ten times the assessment of land under the Rachanhalli tank (*vide* para. 8 of addendum to the report).
Annual cost of working	91,000	61,000	65,000	71,600	68,000	
Cost of water per 1,000 gallons .. Rs.	0 5 0	0 3 3	0 4 3	0 4 7	0 4 6	

(Signed) J. C. LARMINIE,
Executive Engineer.

4th March 1889.

BANGALORE WATER-SUPPLY.

COMPARATIVE STATEMENT of annual working expenses for the Rachanhalli Tank Project. Estimates to store a supply for three different periods.

	ESTIMATE PERCENTAGES AND WORKING EXPENSES.								
	For 12 months' supply.			For 18 months' supply.			For 24 months' supply.		
	Item of estimate.	Per cent.	Annual charge.	Item of estimate.	Per cent.	Annual charge.	Item of estimate.	Per cent.	Annual charge.
	Rs.		Rs.	Rs.		Rs.	Rs.		Rs.
Machinery	45,000	15	6,750	45,000	15	6,750	45,000	15	6,750
Iron piping valves, &c. ..	1,94,140	7	13,589	1,94,140	7	13,589	1,94,140	7	13,589
Do. distribution ..	2,29,744	7	16,082	2,29,744	7	16,082	2,29,744	7	16,082
Balance of estimate on which ordinary interest is charged ..	2,67,750	4	8,310	2,36,750	4	9,470	2,35,800	4	11,824
Total of estimates ..	6,76,634	..	..	7,05,634	..	..	7,04,484	..	..
Establishment.									
One Head Engineer on Rs. 200 ..	..	..	2,400	..	..	2,400	..	..	2,400
Two engine-drivers on Rs. 20 ..	..	..	480	..	..	480	..	..	480
Four stokers on Rs. 8 ..	..	..	384	..	..	384	..	..	384
One Superintendent of Filters and Distribution on Rs. 15 ..	..	..	180	..	..	180	..	..	180
Four lascars or turn-cocks on Rs. 7	..	..	336	..	..	336	..	..	336
Cleaning filters and settling ponds	..	..	5,000	..	..	5,000	..	..	5,000
Fuel.	920 lb. per hour. 3,714 hours		11,482 1,900	..	..	11,482 1,900	..	..	11,482 1,900
Small stores	..	..	..	..	..	..	..	..	70,497
Total annual cost of 250 million gallons ..	..	..	68,893 1,107	..	..	68,053 1,147	..	..	1,193
Contingencies, repairs, &c. ..	..	..	..	..	..	..	..	..	71,690
Total cost for 250 million gallons ..	..	..	68,000	..	..	69,200	..	..	
Rate per 1,000 gallons delivered .. Rs.	..	..	0 4 4	..	..	0 4 5	..	..	0 4 7

(Signed) J. C. LARMINIE,
Executive Engineer.

4th March 1889.

From Sir J. A. HANBURY, M.B., K.C.B., Surgeon-General, Her Majesty's Forces, to the Secretary to Government, Public Works Department, dated Ootacamund, 25th March 1889, No. 822.

In reply to your letter No. 1223 C., dated 9th instant, I have the honor to inform you that, basing my opinion on the statement of analysis received from you, I consider the water of good quality and fit for the use of the troops and townspeople.

From Surgeon-Major J. A. LAING, Sanitary Commissioner for Madras, to the Secretary to Government, Public Works Department, dated Ootacamund, 10th April 1889, No. O/1.

With reference to your letters, Nos. 1222 C. and 1620 C., received 11th March and 1st April, I have the honor to state that I have visited Bangalore and inspected the catchment basins mentioned in Mr. Larminie's reports,* and submit the following remarks as regards the quality of the waters.

2. In deciding upon a water-supply, the value of the supply must be determined by a local examination of such proximate and remote conditions as may affect its

* Herewith returned as requested with map.

purity. The cleanliness and nature of the gathering grounds, extent of cultivation, the amount of manuring, &c., and points of a similar kind have to be considered and supplemented by a chemical examination. In the schemes mentioned in Mr. Larminie's report, the tanks or reservoirs are to be filled with the rain-water that runs over the surface; so the cleaner that surface is the purer will be the water collected. In none of the schemes, however, will the water be entirely free from the risk of contamination from surface drainage, as in each catchment area there are villages and manured cultivated lands. The gathering ground of the Mágadi road scheme is one which is least objectionable and which is most promising as regards the purity of the water. In this catchment area there are very few villages (and those are small ones), very little cultivation, and that with crops but slightly manured. The catchment area of the Hebbal, Rachanhalli and Nagavaram schemes cannot be considered at all clean, and, as they at present stand, could not be expected to give a wholesome supply of water. Cultivation is carried on in them to a considerable extent, and in places with crops which are highly manured and in the Hebbal and Rachanhalli catchment areas there are also many villages. The waters of the Hebbal, Rachanhalli and Nagavaram tanks or reservoirs would therefore be liable to dangerous contamination as they would not only flow over highly-manured cultivated lands, but the tanks would also receive the surface filth of the villages situated in their catchment areas.

3. While at Bangalore I requested the Deputy Commissioner to favor me with the number of villages, population of each, extent and kind of cultivation in each catchment area; but this information has not yet been received. I will forward it immediately I receive it.

4. From an examination of the catchment areas the Mágadi road scheme, as mentioned above, is the one which will give, as regards quality, the best water, and this is also borne out by the chemical analyses, copies of which I have received this morning from the Chemical Examiner and herewith enclose. It is not stated at which part of the stream (Mágadi road) the sample was taken, but, if this was known, the amount of nitric acid, &c., found on analysis might be explained. According to Mr. Larminie's report, dated 2nd February 1889, *vide* para. 11 (4), the water of the Mágadi road scheme, which was analysed, was taken from the stream under unfavorable circumstances, yet the results show it to be a much better water than either that of the Hebbal or Dhasarhalli (Rachanhalli) tanks. The remarks made regarding the Mágadi road water apply also to the Hebbal and Dhasarhalli tank waters, but to a much greater extent. From an examination of the catchment areas and from the chemical analyses, the Hebbal and Dhasarhalli water-supplies are shown to be subjected to annual pollution, and as there is always danger lurking in a water which is known to be contaminated with animal matter, they are not in my opinion advisable sources of drinking-water supplies. The scheme therefore which I would recommend is the Mágadi road one, as from a sanitary point of view it undoubtedly would give purer water than either the Hebbal or Dhasarhalli.

ENCLOSURES.

		Mágadi road.
Total solids	Grms. per litre	0·250
Volatile solids	Do.	0·070
Chlorine	Do.	0·011
Total hardness	Clark's scale	2°·450
Permanent hardness ...	Do.	0°·875
Free ammonia	Mlgrms. per litre	Trace.
Albumenoid ammonia ...	Do.	0·200
Nitric acid	Do. (as ammonia) ...	0·300
Apparent quality of the water as inferred from the results obtained on examination		*Nil*

Remarks.—The physical characters of the water are unfavorable; the thick reddish sediment under the microscope showed abundance of siliceous particles ("river sand"), a few infusoria and masses of disintegrating vegetable tissue. The volatile solids are suspiciously high and the albumenoid ammonia excessively so, probably due to vegetable pollution, but the

amount of nitric acid indicates the necessity for a careful sanitary survey of the catchment area, in the neighbourhood of the position at which the sample was taken, in order to make sure of the absence of any sources of animal pollution.

			No. I Hebbal tank, 5 miles north of Bangalore.	No. II. Dhassarhalli tank, 6 miles north of Bangalore.
Total solids	Grms. per litre		0·460	0·220
Volatile solids ...	Do.		0·090	0·110
Chlorine	Do.		0·014	0·025
Total hardness ...	Clark's scale		2°·100	2°·800
Permanent hardness ..	Do.		1°·750	1°·575
Free ammonia ...	Mlgrms. per litre		Trace.	Trace.
Albumenoid ammonia.	Do.		0·240	0·200
Nitric acid ...	Do.	(as ammonia) ...	0·750	0·600
Apparent quality of the water as inferred from the results obtained on examination			Suspicious.	Suspicious.

Remarks.—Large amount of vegetable matter present in water, also fine clay sand.

(Signed) J. L. VAN GEYZEL,
Chemical Examiner.

ORDER—dated 18th May 1889, No. 1326 W., Public Works.

With G.O. dated 16th July 1888, No. 2147 W., was forwarded to the Government of India a note by the late Chief Engineer Colonel Hasted, R.E., on the several schemes for supplying water to the troops in Bangalore which had been elicited by the offer of a prize of Rs. 1,000 by this Government, and in pursuance of the recommendations therein made, Mr. J. C. Larminie, Executive Engineer, was placed on special duty to work out those of the suggested schemes which appeared most promising. His reports are read above, and also those of the Surgeon-General, Her Majesty's Forces, and the Sanitary Commissioner, Madras, on the quality of this water, and of the sources in question.

2. The schemes investigated by Mr. Larminie were—

(1) *The Mágadi Road Scheme*, which was that proposed by Mr. Standish Lee in the prize essay. Two projects for supply from the Mágadi road valley have been investigated, the one to yield sufficient for the whole civil and military station, and the other for supply for the troops alone.

(2) *The Hebbal Valley Scheme.*—General Fischer proposed to utilize this valley as a source of supply for the troops and the civil and military station, and for the pettah or native town, or a population of 150,000 in all; but it has been shown that this is impracticable and Mr. Larminie's project for this valley contemplates supplying the civil and military station (*i.e.*, the troops and cantonment) only.

(3) *The Nagavaram Scheme*, which contemplates the utilisation of the Hebbal catchment area in addition to a further tract lower down, involving a higher lift.

(4) *The Rachanhalli Scheme*, which depends upon a valley lying to the north of the last two. All these schemes are similar in character and propose the construction of storage reservoirs whence the water is to be pumped to a service reservoir on the Mantapam hill. After filtration it is to be distributed thence by gravitation to the cantonment and barracks. The quantity intended to be provided is a year's supply at 12½ gallons per head per diem for 5,000 troops and 6¼ gallons for the remaining population of the civil and military station taken at 100,000. The garrison supply scheme provides only for the troops at 12½ gallons per head per diem.

3. The following are particulars of the cost, &c., of the several schemes as worked out by Mr. Larminie :—

For a year's supply.	Mágadi Road.		Hebbal.	Nagavaram.	Rachanhalli.
	Civil and Military station.	Garrison only.			
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Cost for works	9,02,124 0 0	2,34,130 0 0	5,98,254 0 0	6,55,054 0 0	6,76,634 0 0
Annual charges (including interest and depreciation).	91,000 0 0	26,000 0 0	61,000 0 0	65,500 0 0	68,000 0 0
Cost per 1,000 gallons ..	0 5 9	0 14 0	0 3 3	0 4 3	0 4 6

The Government are of opinion that any scheme to be satisfactory should provide for the storage of at least 18 months' supply ; and the cost of this has been estimated for the Mágadi road and Rachanhalli projects, and also of a two years' supply in that last named. From paras. 63, 64, 70 and 71 of Mr. Larminie's report it appears questionable whether more than one year's supply could be counted on or stored at Hebbal or Nagavaram, and certain that the additional cost would be very great. The following are the results for the larger supplies in the Mágadi road and Rachanhalli projects :—

	Mágadi Road.	Rachanhalli.	
	One and half years.	One and half years.	Two years.
	Rs. A. P.	Rs. A. P.	Rs. A. P.
Works	9,79,754 0 0	7,05,634 0 0	7,64,484 0 0
Annual charges	94,105 0 0	69,200 0 0	71,600 0 0
Cost per 1,000 gallons	0 5 11	0 4 5	0 4 7

4. From the figures above given, it appears that the garrison supply scheme may be left out of account, and that the Hebbal scheme, for one year's supply, is the cheapest. As regards quality of the water, the Mágadi road catchment gives by far the purest supply, and that of Rachanhalli is appreciably better than that of either Hebbal or Nagavaram. The Surgeon-General, Her Majesty's Forces, is of opinion that the Rachanhalli water is of good quality and fit for the use of the troops and towns-people ; but the Sanitary Commissioner after an examination of the catchment areas gives unqualified preference to the Mágadi road scheme, and considers the others dangerous as the catchments contain villages and cultivated and manured lands. The Governor in Council while admitting that the objections of the Sanitary Commissioner have force, observes that they apply also in some degree to the Mágadi road basin, which itself is not quite clear of cultivation. The cost of obtaining a catchment of adequate extent and free from the dangers adverted to anywhere near Bangalore would be prohibitive, and the Governor in Council considers that the water of any of the sources examined may be regarded as practically safe, and that the opinion of the Surgeon-General may be accepted. There is no doubt that any of them will be, so far as quality in concerned, a vast improvement on the existing supply.

5. The Rachanhalli scheme presents undoubted advantages over Hebbal and Nagavaram. These as being nearer Bangalore are more exposed to contamination by manure; the basins are not so favorable either for catchment or storage ; and the quantity of supply, if sufficient can be obtained at all, is much less assured. The Jakkur tank being superseded, the "free catchment," *i.e.*, the area draining directly into the Rachanhalli reservoir, will be treble that at Hebbal and nearly double that at Nagavaram. There is no doubt at all that an ample supply can be obtained from the Rachanhalli valley, and the cost of the water is hardly in excess of that at Nagavaram. As compared with Mágadi road the water may be somewhat less

pure, but the considerably larger catchment at Rachanhalli and the great cheapness far outweigh this disadvantage in the opinion of the Governor in Council.

6. A further reason why the Rachanhalli should be preferred to the Mágadi road scheme is that the appropriation of the latter valley would interfere with the claims of the Mysore Government upon it as the most natural and attainable source of supply for the pettah or native town of Bangalore. The lift from it to supply the pettah would be much less than is necessary to gain command of the civil and military station, and it may be said roughly that 1½ years' supply for the latter would be only a year's supply for the two together. It is, moreover, doubtful whether the catchment area as taken by Mr. Larminie would yield 1½ years' supply for both the cantonment and native town. With the claims of the pettah, on Sankey's tank, adverted to in the papers forwarded with the Resident's letter read above, the Government of Madras has nothing to do; but the Governor in Council is strongly of opinion that, whatever be done as regards the supply of the pettah, it is very desirable that an independent source should be adopted for that of the cantonment and the troops.

7. For the foregoing reasons, His Excellency the Governor in Council resolves to recommend to the Government of India the adoption of the Rachanhalli scheme, for at least an 18 months' supply, as the most suitable. How this scheme is to be financed and how this burden should be shared between the military budget and the municipality are matters for the decision of the Governor-General in Council.

8. Ordered that the following letter be addressed to the Government of India, Military Department.

(Here enter No. 1327 W., dated 18th May 1889.)

(True Extract.)

(Signed) R. R. E. DRAKE-BROCKMAN, Lt.-Col., R.E.,
Ag. Joint Secy. to Govt., P.W.D.

To the Political Department, for communication to the Resident in Mysore.
" Military Department.

Exd. J. Henriques.
Spare Copies

15/1000

BUILDINGS AND ROADS.
MILITARY WORKS.

Govt. of {1889} Madras.

PUBLIC WORKS.

Dated May, 18*th*

Read. *Encl.*

G.O., 18th May 1889, No. 1326 W.

MAY.

Water-supply of Bangalore

Orders on report from Mr. Larminie, Executive Engineer, on the several schemes for the —.

BUILDINGS AND ROADS.
MILITARY WORKS.

Govt. of {1889} Madras.

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Dated May, 18th

Read. *Encl.*

G.O., 18th May 1889, No. 1326 W.

MAY.

Water-supply of Bangalore

Orders on report from Mr. Larminie, Executive Engineer, on the several schemes for the —.

16/1000

BANGALORE WATER SUPPLY.

Supplemental Report on the proposal to supply the Garrison and Cantonment from the Rachenhalli (or Dasaralli Tank.)

The report which has been already submitted treats of the question of obtaining a supply from three sources,

REFERENCE.
Para 74 of report which accompanies the estimates which have been already submitted.

1st—Magadi Road
2nd—Hebbal Tank
3rd—Nagavara Tank.

The first named is likely to prove an expensive scheme, both for first construction and subsequent working, and is not besides without its draw-backs, the chief being the uncertainty attendant on the construction of a new masonry dam.

2. The two latter schemes completely fail when considered in the light of the data decided on, chiefly owing to the small areas of free catchments available; consequently a source of supply which, while combining the advantages of the two latter schemes i. e., comparatively high level and proximity to Bangaloro, with a larger catchment area, would comply with the necessary requirements. The Rachenhalli Tank fulfils these conditions fairly well.

3. It is just ¾ of a mile further out, to the north, than the Nagavara Tank and almost at the same level: the accompanying comparative statement compares its particulars with those of the three schemes for the combined supply as already submitted.

4. The conditions of the catchment basin are more favorable than those of either Hebbal or Nagavara Tanks.

(*a*) As to the total area, i. e. 36 square miles, and here it may be remarked that under the conditions of rain-fall prevailing in Mysore a large catchment, though even not free, is of value, as the chances then of catching local showers are so much better. Major Kensington, R. E., who has had considerable experience of Mysore, considers that, by far the best tank filling rains, are not those of the monsoons, but the local showers that fall before and after each monsoon; this quite agrees with the experience (limited of course) gained during these investigations, and it is from these very local showers, which usually come down in sudden heavy bursts of short duration, that the greatest percentage of run-off is obtained.

(*b*) The catchment is not so highly cultivated and being further from Bangalore and more out of the way, receives but little, (if any) of the clearances from the dust bins. The good quality of the water is shown by the table of analysis.

(*c*) The catchment is steeper and narrower, and observation after heavy rain showed a rapid and copious run-off.

(*d*) The catchment of 15 square miles, which may be considered free, is colored burnt sienna, on the 1 inch Topographical sheets which accompany the first report.

5. It is true that several tanks appear in this area, but the principal one, the Jukkur, would disappear, as its ayacut would be submerged by the raising of water level in the Rachenhalli Tank, so under the head land compensation, provision is made for taking up this area (only 87 acres). All the other tanks are shallow ponds of no importance.

18/1000

SUPPLEMENTAL.

BANGALORE WATER-SUPPLY.

Comparative Statement showing cost and other particulars of the various schemes proposed for a combined supply to Garrison and Cantonment.

	Magadi Road Maligal.	Hebbal Tank.	Nagavara.	Rachenhalli.	
Distance from source of supply to Service Reservoir.	5 miles.	2¼	3	4	
Head to be pumped against	356	162	186	194	
Lowest take off level	2741·71	2918·0	2897·0	2895·0	2 lower than Nagavara, Tank being deeper.
Delivery level in settling ponds	3090·0	3090·0	3090·0	3090·0	
Areas of Reservoirs at F. S. L.	84·76 acres.	361·0	334·6 acres.	338 acres.	
Capacities of do at do	60·54	123·4	106 M. C. feet	118 M. C. F.	For one year's supply.
Total catchment area	9	13	16·6	36 Sq. miles.	
Free do do	9	5·0	3·6	15	
	ABSTRACT OF ESTIMATES.				
Dam	1,92,740	25,650	30,500	16,000	
Engines, Pumps and Boilers	53,000	40,000	44,000	45,000	
Connection with Reservoir	1,000	...	...	...	
Pump well	1,500	1,500	1,500	1,500	
Engine and boiler house	12,000	12,000	12,000	12,000	
Chimney	5,000	3,000	3,000	3,000	
Quarters for establishment	14,000	14,000	14,000	14,000	
Supply Main	2,57,000	1,15,400	1,51,900	1,94,400	
Settling Ponds	37,350	37,350	37,350	37,350	
Filters	36,860	36,860	36,860	36,860	
Service Reservoir	53,430	53,430	53,430	53,430	
Town distribution	2,29,744	2,29,744	2,29,744	2,29,744	
Compensation for land submerged by Reservoir	85 acres at Rs. 100. 57 „ „ 150. 30 „ „ 200. 8,500	100 acres at Rs. 100 „ „ 150 18,550	200 acres at Rs. 100 „ „ 200 30,000	68 acres dry at Rs. 100 87 „ wet at „ 150 19,850	87 acres wet ayacut of Jakkur Tank sub-merged by raising of Rachenhalli Tank.
Do for land deprived of water ...	...	Assessment×10 10,770	10,770	Assessment×10 13,500	
Total.....	9,02,124	5,98,254	6,55,054	6,76,634	
Annual cost of working.....	91,000	61,000	65,500	68,000	
Cost of water per 1,000 gallons.....	Rs. 0—5—9	Rs. 0—3—3	Rs. 0—4—3	Rs. 0—4—8	6

19/1000

Report to accompany the Estimate for Water-Supply to the Cantonment and Garrison of Bangalore and to the Estimate for supply to the Garrison alone.

In accordance with No. 3 reference, instructions were given for the investigation of two schemes for the supply of water to Bangalore.

1st.—That proposed by Mr. Lee, to whose essay was awarded the reward of Rs. 1,000 (reference No. 2), and 2nd, that proposed by Major Kensington.

2. The instructions given were general, and were to the effect that, every item composing the estimates was to be gone into in minute detail and most carefully estimated for.

REFERENCES.

(1) Letter from the Government of India No. 1182 M. W. of 14th June 1887 recorded in G. O. No. 1924 W. of 18th July 1887.

(2) G. O. No. 2810 W. of 20th October 1887.

(3) Chief Engineer's Note printed with G. O. No. 2480 W—A of 14th August 1888.

(4) Chief Engineer's Note printed with G. O. No. 25 W of 8th January 1889.

3. Accordingly, some time was devoted to consideration, from every point of view, of each detail. Mr. Lee's, commonly called the Magadi Road scheme, being the most promising, was first taken in hand.

4. The country was carefully examined to secure the best site for the dam, as also for the best and most economical line for the Supply Main to Bangalore, and endeavours were made to obtain further data regarding rain-fall and run-off.

5. Some time was also devoted to the preparation of a fairly accurate survey with levels and contours of the proposed Magadi Road Reservoir, site and the design of the masonry dam was made out in detail.

6. According to somewhat modified instructions received in December, Reference No. 4. approximate estimates, to admit of a comparison of the various schemes, were considered in the first instance sufficient. Had it been understood that sketch plans and estimates were only required, the work could have been done much sooner; as it is, the projects are now submitted well within the two months mentioned, (Reference No. 4.) However it is hoped that the time which has been devoted to minor detail will be of value hereafter. For, of the estimates herewith submitted, that for the Magadi Road scheme has been prepared in considerable detail, and is believed to be a very close approximation of what the work may be expected to cost.

7. To the Nagavara scheme, that for the Hebbal tank, and for the smaller scheme for the Garrison supply (instructions regarding the two latter received in December last) it has not been possible to devote so much attention. The surveys and estimates are however believed to be close approximations.

8. The accompanying comparative statement gives the leading features of the several schemes and their estimated cost. Each scheme will now be reviewed in Reference No. 4. detail. They have all been based on the same general data as laid down in the Chief Engineer's Note, and regarding which a few observations may, it is hoped, be permitted. (Vide paras 12 to 18.)

9. The more correct name for this scheme would be Maligal, near which Magadi Road or Maligal Scheme. *village it is proposed to construct the reservoir. The catchment area of 9 square miles (as measured on the Topographical Survey vide sheets 42 and 63) extends 3 miles to the north and 1 mile to the south of, 2 miles of the road from Bangalore to Magadi (4½ to 6½ miles).

*Situated about one mile below the bridge over the stream at furlong stone 5/6 on the Magadi Road.

10. In every particular except cost, it is by far the most promising of the three schemes investigated for the supply of the Cantonment and Garrison. But, provided a scheme is admitted to be promising in other particulars, the mere question of even a few additional lakhs to the cost should not, it is thought, weigh much against it. The comparative statement shows the small additional quantity of *water (some 20 M. C. feet extra for a year's supply) which has to be stored to provide for loss from evaporation, leakage, etc., owing to the favorable conformation of the reservoir site, a narrow deep valley, the area of waterspread at F. S. L. being 85 acres.

11. The other advantages are :—

Advantages of Maligal Scheme.

(1) The whole of the catchment may be considered free.

(2) Probably not more than one-sixth of the area is at present under cultivation ; there is however a growing tendency to extend it, chiefly casuarina plantations ; so the Mysore authorities have been requested to check its further extension for the present.

(3) The catchment area chiefly consists of steep, bare lateritic Hills, from which personal observation showed that even moderate showers are very quickly run off (vide also para 18 of Chief Engineer's Note, reference No. 3.) In this connection also vide paras 17 to 19 regarding percentage of run-off.

(4) Analysis of the water taken from the stream under unfavorable circumstances—shortly after a flood—shows it to be remarkably pure, and the accompanying table compares it with water from the other sources, as also with that now pumped up for the use of the Bangalore Garrison. Even in the dryest season there is, it is stated, a small stream of pure water always flowing.

(5) A supply for more than one year can be more advantageously stored here than elsewhere.

12. Regarding the quantity of water to be stored, i. e. 40 M. C. feet or only *one year's* supply. As a comparison between the various schemes, it may suffice to estimate for storing this quantity ; but it is considered that with only one year's supply in store a bad season or two cannot possibly be tided over.

Quantity of water to be stored and run-off catchment area.

13. The minimum supply, 7 M. C. feet per square mile of catchment, which according to the accepted Mysore data might always, it was thought, be expected to flow off, cannot, it is *now found*, be counted on as a certainty.

14. Seven M. C. feet means 3·01 inches of rain, run off each square mile. Taking 17″ as the lowest rain-fall 3·01″ would be almost 18% of that total fall, while there is abundant evidence to show that, to obtain so high a percentage the fall must be in sharp heavy showers. Everything depends on the character of the rain fall. In the course of only an average year's fall (36 inches) *provided* that some of the falls come down in quick heavy bursts, the 18% might safely be counted on, while light continuous rain, although the 24 hours' fall might be high, would yield a much smaller percentage.

Experience of 2nd November last. Light continuous rain 5 inches in 24 hours. Percentage received by Saukey's Tank, 18 per cent.

15. The lighter the annual rain-fall the smaller and fewer are the chances of obtaining heavy showers of short duration, so that in a season of minimum fall, it may happen and very probably will, that the run off, instead of being 7 M. C. feet per square mile, will be almost nil. (This, it is known, on the best authority, has already been experienced at the Mysore water works). Consequently, how essential would it not seem to store as large a supply as can consistently be done ?

16. Two and even three years' supply have been advocated. The reports that have during these investigations from time to time been submitted regarding the Magadi Road scheme, advocated the storing of 1½ years' supply (60 M. C. feet), which requires, allowing for waste, evaporation, &c., as near as can be 100 M. C. feet in the reservoir. (Vide table of consumption and waste).

* 40 M. C. F. required for supply of the Cantonment and Garrison, so 60 M. C. F. must be stored for a year's supply.

200/1000

17. That this quantity can be impounded in an average year is hardly open to question. The Mysore data gives 11 M. C. feet per square mile as the *average*, as deduced from Sankey's Tank, a most unfavorable catchment. As noted in para 18 of Chief Engineer's *Note, the run off of the Magadi Road catchment must be higher, and observations made during the course of these investigations give the following approximate results.

*Reference No. 3.

18. During the period 11th September to 2nd October last, the total fall from certain selected showers was 5·4 inches. This fall over the catchment (taken as only 8½ square miles) means 106·63 M. C. feet.

The quantity that passed down the stream was approximately computed to be †42·71 M. C. feet. $\frac{42·71}{106·63}$ = 0·4 or 40 per cent average. Individual falls gave for ½ an inch in 1½ hours, (*after a long period of draught*) 3 per cent. Even on this occasion the stream began to increase half an hour after the rain commenced.

†Sufficient for a year's consumption.

For a 2 inch fall	.. ..	58 per cent.	
„ 1·3 „	.. ..	29 „	
„ 1·1 „	.. ..	40 „	
„ 0·5 „	.. ..	30 „	Catchment by this time well wet

All these were falls of short duration from 1½ to 3 hours.

19. But although the data is admittedly very approximate, still it suffices to show what may be expected in an average year. The year under reference was however under the average, as the total fall was only 34 inches.

20. To impound 1½ year's supply, 100 M. C. feet, 4·78 inches of rain must run off the 9 square miles of Magadi Road catchment, or only 13·3 per cent of an average year's fall.

21. The dam, to impound this quantity, should be 9½ feet higher than that for one year's supply now estimated for (see section), and the *additional* cost, as per detailed estimate, for a masonry and concrete dam for the full width of this section would be Rs. ‡77,630.

‡ Rs. 2,70,370 − 1,92,740 = 77,630

22. The advantages of the scheme are detailed in paragraph 11. The chief disadvantage will now be alluded to : it is that the run off being so very quick the water, even in small freshes, comes down highly charged with silt. It is consequently proposed not to draw off water below 13 feet above bed of stream at site of dam (level 33·48 on survey), thus utilizing a length of the river bed as a silt trap ; with a view to keep this clear it is proposed to place two or more 3 foot iron pipe scouring sluices worked by equilibrium valves in the foot of the dam, and a special design for these valves has been partly worked out. But even with all possible precautions it is feared that silting up will go on.

Disadvantage.

23. Messrs. Richardson and Cruddas, the well-known Engineering Firm of Bombay, have taken considerable trouble in furnishing particulars and cost of the best description of pumps and engines to work against the Heavy Heads involved in the three schemes, that of Magadi Road being greatest. The Heads in each case have been deduced as follows, Magadi Road being taken as an example.

Pumping Engines.

Top water level in settling ponds	3090·0 M. S. L.	
Lowest off take at Reservoir	2741·71	
Actual lift....	348·29 feet	
Pumps can be placed 25' above draw off ..	25	
	323	
Head allowed to overcome friction in supply main to Bangalore at 6' per mile	33	
Total Head to pump against....	356 feet	

24. It was specified that the pumps should be able to throw up a week's supply in six days of twelve hours, or at the rate of 66,540 gallons per hour.

25. For this work Messrs. Richardson and Cruddas recommend three sets of engines, pumps and boilers, any two of which working together shall work up to the required quantity, leaving a third (engine, pumps and boiler) in reserve.

26. They recommend, direct acting, compound condensing engines and pumps.

High pressure steam cylinder ..21 inches diameter
Low pressure.. .. ..36 inches.
Pumps 48 inches stroke ..12 „ diameter, and
Lancashire boilers each of 35 H. P. nominal.

Their estimate for three sets of the above delivered in Bangalore is Rs. 53,000.

27. An idea of the combined pump and engine can be obtained from the wood cut at page 35 of Messrs. Richardson and Cruddas' catalogue. The wood cut, however, does not represent a compound engine. It is extremely compact, each pump and engine only occupying a space of $28' \times 3\frac{1}{2}'$, so the three pumps can be arranged alongside in a room measuring about $48' \times 35'$. These pumps are made for lifts from 250 to 1,500 feet, for quantities of water from 3,000 to 50,000 gallons per hour.

28. A provision of Rs. 12,000 has been made for engine and boiler houses. A detailed estimate has not been made out, as one amounting to Rs. 9,260, based on very liberal rates, was framed in connection with the Agram Tank scheme; rather more accommodation will be required in this instance, for which the extra Rs. 2,940 will be sufficient provision.

29. The Agram Tank scheme estimate for quarters, Rs. 14,000, has also been adopted; provision is made therein for quarters for one European Engineer and two European or Eurasian drivers, for native stokers, and for a store room and office, the whole surrounded by a wall, &c. At Magadi Road (Maligal) a good site for the quarters will be on the Hill top above the right end of the dam.

30. As in Maligal Reservoir with one year's supply stored, there will be $31\frac{1}{2}$ feet difference of level between highest and lowest water levels, and as pumps cannot be placed more than about 25 feet above the lowest level to be pumped from, to avoid the necessity of placing the pumps below engine level, it has been decided to place the pumps in rear of the dam, the site marked on the survey will be a suitable one. Although perhaps not so safe, as if placed above the dam and above M W L, the arrangement admits of the cheaper and more compact form of engine described.

Site for Engines and Pumps.

31. To store one year's supply a dam 45 feet above present bed of stream at the proposed site will be required. At the centre section a height of $50\frac{1}{4}$ feet has been allowed for; the cross section of the valley at site shows the various levels of foundations proposed; they are probably lower than will be found necessary.

Dam of masonry and concrete.

32. The site selected is a little higher up the stream than that intended by Mr. Lee. At the latter, the line of strike of the rocks, with all the joints and fissures, are parallel to the axis of the stream, while higher up the line of strike is perpendicular to the river, and the bed of rock is much harder and sounder as far as can be judged by gullies, trial pits and other indications. This bed of rock extends all over the valley at no great depth.

33. Taking the Bhim Tal dam near Naini Tal as a precedent, it is proposed to form this dam of two outer skins or walls of coursed rubble in cement mortar, thus obviating the necessity for supporting planking when carrying up the concrete hearting of the dam. It was intended to use Portland cement for the entire mass of concrete, but the Chief Engineer being of opinion that an outer casing of cement concrete would be sufficient, the estimate has been framed accordingly, allowing for the rubble casing in front and rear, and a thickness of 2 feet of the concrete in rear of the front rubble face to be in cement mortar. The remainder of

the concrete to be of ordinary lime mortar. The additional cost of the dam, laying all the concrete in cement, would be *Rs. 77,353. Probably a lighter section than has been estimated for near the flanks would suffice.

3,223 at Rs. 24, the difference of rates for cement and lime concrete.

34. A diagram showing the section of the dam with the curves of pressure, and a table of weights and pressures and also the required dimensions if calculated by Molesworth's formula, accompanies the estimates.

35. After some consideration the right end of the dam was fixed on as the best site for a surplus weir; there is evidently a bed of rock at no great depth below the surface, a trial pit shows rock at level 55·0. The weir has been designed for a drop, still 5 feet lower, of a type which has been found to answer well and is much less expensive than a clear drop.

Surplus arrangements.

36. As designed the 150 feet of weir with a depth of 3 feet passing over, will discharge $\frac{1}{2}$ an inch of rain per hour from the catchment of 9 square miles.

37. According to Mysore Public Works Department experience, as much as 1 inch per hour from a catchment of this area and description may occasionally be expected; but to provide a weir for so exceptional occasions seems unnecessary, as an arrangement might be made to pass such excessive rain-fall over the dam. The staff in charge of the pumping machinery could easily look after and work any simple arrangement decided on. Water so surplussing will fall on the rear slope of the dam, up to depth over crest of 3 feet.

38. As shown on the reservoir survey, the weir bye wash bed, is placed at +50 and carried along till this level runs out of cutting, where the surplus can be passed over the rock into an existing ravine. It is believed however that a rocky bed will be met with above this level (i. e.+50).

39. The left embankment of the bye wash can be formed from the cutting, provision is made for a substantial, grouted and pointed revetment to it, for a length of 400 feet below the weir rear wings.

40. The pump valves will be placed at level 58·48 or 25 feet above the lowest take-off level in the reservoir, from the pumps the supply main to Bangalore will be carried round the left side of the reservoir for a short distance and thence strike away in a north easterly direction, crossing the road from Bangalore to Magadi near furlong stone $\frac{5}{6}$; thence the line will run, with three slight bends, to the Mantapam Hill, where it is proposed to place settling ponds, filters and service reservoir.

Supply Main to Bangalore.

41. The line will not pass near the Pettah, and in selecting it (the line) the objects kept in view were to secure the shortest route, subject to facilities of laying and the avoidance of sudden rises and dips, two or three small ravines will have to be crossed, for which a lump sum provision has been made in the estimate, the cheapest arrangement will be to support the pipes on the rough stone posts so universally used, or on light bridges formed of old rails. The line crosses the Mysore State Railway to Tumkur about a mile north of the Pettah terminus.

42. As the pipes nearest to the reservoir have the heaviest Head to withstand, a heavier section of metal has been allowed, 1″ in thickness for the first mile, $\frac{13}{16}$″ for the next, and $\frac{3}{4}$″ for all the rest. For practical reasons the pipes cannot well be of less thickness than $\frac{3}{4}$″. A sufficient number of scour cocks, air and back or reflux pressure valves have been allowed for. All the items and rates have been carefully considered.

43. As noted in para 23, the size of the main has been calculated (as also for the other schemes) taking a head of 6 feet per mile, the week's supply being pumped up in 6 days of 12 hours $\frac{7,70,000 \text{ cubic feet}}{72 \text{ hour} \times 60 \times 60} = 2{\cdot}96$, say 3 cubic feet, required discharge per second. An 18″ pipe by Kutter's formula will at 6′ per mile, discharge rather more, or 3·4 C. per 1″. However a 17″ pipe would be too small, discharge 2·86 feet per 1″; so the larger size has been adopted.

Size of Supply Main.

Messrs. Richardson and Cruddas, in connection with the engines, considered the size 18″ as specified suitable.

Settling pond, filters and service reservoir,

44. It is proposed to construct these on the Mantapam Hill. The only disadvantage of this site is that it necessitates about a mile extra of supply pipe to the Cantonment, but there are several counterbalancing advantages.

(a) The site is at the highest available level.

(b) It is well away from all dwellings and their accompanying sources of contamination.

(c) The land can easily be made available and no existing rights of any consequence will be interfered with.

(d) The only other suitable sites are either the golf ground or the high ground; for the former floor of service reservoir should be placed at level 3030, for the latter 3040, thus reducing the head for distribution, and neither site affords the same facilities for construction, and they are besides much used as recreation grounds by the officers of the Garrison and other European residents. The constructions in question would completely spoil either.

(e) The site selected on the slope of the Hill admits of the settling ponds, filters and service reservoir being arranged at suitable levels with reference to one another (vide Plan No. 14).

(f) For either Hebbal or Nagavara schemes the one disadvantage noted disappears.

(g) Borings to a depth, lower than necessary for excavation, shew the soil to be pretty similar to that visible on the surface, i. e., hard compact lateritic soil; mixed with water the clay from the borings seemed almost fit for puddle, so that there can be no objection to constructing ponds, filters and service reservoir as proposed, i. e., in cutting, with a good facing of cement concrete laid on the slopes, cut into steps, if constructed with masonry sides, the works would be considerably more expensive.

45. The question of placing these works near the supply reservoir has been considered and the idea abandoned as it would involve additional pumping, as there is no suitable site below the reservoir where they could economically be constructed. The pumps proposed are specially adopted to the pumping of muddy water.

The plan shows the general arrangements.

Details.

46. The settling ponds have been designed for a depth of 8 feet of water, of which 7 feet can be drawn off leaving 1 foot of depth for silt accumulation, each pond to hold one day's supply. It will be a question for future consideration if a greater number of ponds should not be provided. With a view, to deliver the water into the ponds as quietly as possible, the supply main from the pumps will deliver into a large circular well, whence the water will be conveyed by iron pipes, regulated by valves, to masonry chambers, and thence by over falls which can be regulated by shutters, into the ponds.

47. From the ponds the water will be drawn off by means of adjustable (or floating) suction pipes, which the drawings will fully explain, into the filters.

Filters.

48. Two have been provided for, each capable of filtering a day's supply in 24 hours, at the rate of 50 gallons per square foot per 24 hours. A liberal allowance as, 75 gallons is commonly taken as the duty of a filter. The draw off sluices from the filters to the service reservoir are arranged so that the necessary head on the filters can be arranged to any required extent, from 1 inch up to 3 feet, probably 18″ will be found sufficient; the arrangements for turning the water from either settling pond to either filter are shown on the plan.

99/1000

Service Reservoir.

49. Designed to contain rather more than three days' supply—with a view to keeping the water as cool as possible a roof formed by a series of flat brick arches has been provided. It is now generally admitted that service reservoirs should be so covered in. The rough stone pillars allowed for are universally used in Mysore and they are cheaper, cleaner and occupy less space than brick arches would. Rolled iron beams have been allowed for, but old railway rails would do equally well and would probably be cheaper.

50. Town distribution will now be described when the Magadi Road scheme will as a whole have been considered.

The remarks regarding the settling ponds, filters, service reservior and distribution will be common to the other two schemes for the supply to Cantonment and Garrison, so there will be no need to recapitulate them.

51. The distance fixed, 600 feet, in a straight line, nearer than which water need not be brought to any house, greatly simplifies the system.

The proposed lines of piping are shown on the accompanying two sheets of the Topographical Survey of the Cantonment, and the statement of distribution details gives particulars of the various lines proposed.

52. The original intention was to have worked out the system in greater detail, by taking careful measurements and levels for each line, as also by the preparation of detailed drawings and estimates for each special curve and connection required (as was done for the Ootacamund distribution). But under recent instructions it was not possible to do all this, so the estimate is based on the survey, some of the lines have been levelled and many of the survey B. Ms. checked, and with one exception, the latter have been found to agree well with recently taken levels; some differences have also been found between the levels of the Troop supply cisterns.

53. All the levels connected with the various schemes are taken from B. M. No. 2 at the N. E. corner of the Golf ground opposite this office (No. 6 Bellary Road) gateway; this B. M. was recently moved, but has been again put in at the same level as that given for it on the Topographical Survey 3057·48 M. S. L. A connecting level to the S. W. corner of the office plinth gives a value to the latter of 3056·83. A list of the levels of various other points which have been levelled to accompanies.

*Reference No 3.

54. For purposes of calculation the population has been taken:—Europeans 5,000, Natives 100,000; this latter figure is probably 6,000 over the actual at present, but the allowance of 6,000 for increase is not excessive. It has been *decided to allow 2 cubic feet per day for Europeans and one cubic foot for natives. To properly proportion the pipes statements of the population, street by street, would be required, but no such information is available in the Municipal Office; all that could be obtained was a statement of areas and population, and even this is very incomplete and does not include the whole of the population; however it has been used to some extent and partly by guess, the population has been divided amongst the various lines as shown in the distribution statement, and the sizes of the pipes thus deduced, seem reasonable enough, and are capable of distributing the required quantities in eight hours.

55. The statement of distribution fittings gives the particulars of the various fittings allowed for each line. The European Infantry Barrack cistern will be supplied by No. 2 branch of main line No. 4. This latter line will at its termination near Trinity Church join the existing supply pipes to the Cavalry and Artillery Barracks.

56. Probably here and there, short lengths of extra piping will be required to bring certain localities within the limit of distance, but there is ample provision in the estimate for such contingencies.

57. The rates allowed for actual pipe laying are much lower than were allowed at Ootacamund, but they are believed to be sufficient, each item, lead, yarn and excavation have been separately allowed for.

58. Of the two lines for the main from the reservoir to the bifurcation of the distribution mains, the alternative line to the west is some 700 feet shorter and will probably be preferable, the estimate has been made out for the other, but no great

difference would result, as though the grade would be increased from $\frac{1}{250}$ to $\frac{1}{260}$, the discharge of the pipe would not be materially increased, and so its size 15½" could not well be reduced.

59. From the comparative statement of cost and other particulars, this scheme would at first sight seem most promising. The tank also is well calculated to attract popular attention, situated as it is on the high road to Bellary at no great distance from the station and at a higher level than any of the other sources of supply, a fine looking sheet of water, of 204 acres in extent, at present weir level.

Hebbal Tank scheme.

60. The total catchment area is 13 square miles, of which only 5 square miles are free, as marked by a dark green line on the map, and in considering these schemes it has been decided that only *free* catchment can safely be counted on, and in connection with the run off, even from free catchment, the remarks in paragraph 15 should not be lost sight of.

61. The catchment can hardly be considered a steep one and in the middle it is very flat.

62. The tables of capacity and areas and the table of consumption and waste show that, to store one year's supply (40 M. C. feet) it is necessary to impound 123 M. C. feet, so that 83 M. C. feet would be wasted and lost in evaporation owing to the great water-spread of the tank, which at the level, (7½ feet above weir), required to store 123 M. C. feet is some 361 acres in extent.

Supply required.

63. It only remains to apply the data of run-off, per square mile, of free catchment.

Supply available.

Miles.

5 × 7 = 35 M. C. feet available in a bad season.

5 × 11 = 55 M. C. in an average season.

5 × 17 = 85 Maximum supply.

64. In a year however, of average fall, with the character of the rainfall at all favorable, there can be little doubt that the required quantity could be impounded, as then the run off from the entire catchment of 13 square miles could be counted on. During the progress of these investigations the tank has surplussed several times, but if it be decided, as is believed, to be absolutely necessary, that at least 18 months' supply should be stored, over 200 M. C. feet would be required, involving the raising of the tank about 20 feet and the *submerging of a large area of valuable land.

*Vide contour survey of tank.

65. These do not seem to call for particular notice, the tank bund carries the Bellary Road, hence the necessity for the top width allowed. The present weir is crossed by a bridge of 7 vents of 9 feet each. Provision is made for removing two of the piers and raising the remainder, replacing the arches with rolled iron beams and buckled plates, and raising the weir body wall in rear of the bridge, as shown on the sections.

Estimates.

66. The nature of soil in rear of bund is shown on the bore hole diagram.

67. The distance of the tank from the filters and service reservoir being so much less than Magadi Road, reduces the cost of the supply main and this shorter distance and smaller lift materially reduces the first cost of the engines and the working expenses. The same establishment would, however, it is considered, be necessary, as for the more powerful engines required at Magadi Road.

68. This tank is in the same valley as the Hebbal about 1½ miles lower down to the east. The weir is 23 feet lower than that of Hebbal. Correctly speaking its free catchment is only 3·6 square miles, its total catchment being Hebbal catchment of 13 square miles

Nagavara Tank scheme.

+ 3·6 = 16·6 square miles to obtain the 8½ miles, of free catchment alluded to in G. O. 25 W. of 8th January 1889; the 5 square miles of Hebbal free catchment must be reckoned on.

Major Kensington proposed to increase the catchment and take up the surplus of Jukkur Tank by a catch channel, but the unfavorable opinion reported regarding a work of the kind has been endorsed by the Chief Engineer, so the proposal has not been carried further, indeed the Mysore experience of catch channels is not encouraging, and in this instance, as the tank should be raised 11½ feet, the fall available from the Jukkur tank would not then be sufficient.

69. The tables of capacity and consumption show that, for a year's supply (40 M. C. feet) 106 M. C. feet must be impounded, and to do this weir level must be raised 11½ feet, the water-spread being increased from 86 to 334 acres, the land which would be submerged is valuable, being under wet and garden cultivation. The comparative statement gives (as also for the other schemes) the approximate cost of compensation, and if for this scheme, the Hebbal tank were deprived of the water from the five square miles of *its* free catchment, it would happen that in bad years the Hebbal tank could not supply the land irrigated by it, hence in both estimates appears the same sum Rs. 10,770, compensation for land deprived of water.

Supply required, &c.

70. Applying the data as in para 63

Supply available.

Miles.

8·5 × 7 = 59·5 M. C. feet minimum.

8·5 × 11 = 93·5 M. C. F. in an average season.

8·5 × 17 = 144·5 M. C. F. maximum, against 106 M. C. F. required.

As in the case of Hebbal tank, (para 64) in an average year, a supply from the total catchment might be counted on.

71. To impound 1½ year's supply, though the area submerged, while it would not be so great as at Hebbal, would involve the acquisition of much valuable land.

72. The estimates seem to call for no remark, as they have been prepared on the same lines as the others. The bore hole diagram gives the results of two borings made below the bund.

73. The catchment areas of both Hebbal and Nagavara tanks cannot by any means be considered clean; they are both highly cultivated and being close to Bangalore receive a considerable amount of night soil manure, parts of the Nagavara catchment are most offensive. Neither catchment can be nearly so clean as that of the Hessargatta tank, which has been condemned as a source of supply partly for this reason.

Impurity of catchment areas.

* Reference No. 4.

74. As shown, both Hebbal and Nagavara tanks fail, when reviewed in the light of the data available. So, as has been reported, the only cheap alternative to the Magadi road scheme would be the Rachenhalli (or Dhasarhalli) tank; this is at the same level as the Nagavara tank and only ¾ mile further out to the north. It is in a narrower and deeper valley than the Nagavara and so the water-spread would be smaller, and to store a year's supply it need only be raised about 8 feet. Its total catchment is 36 square miles, of which 15 square miles may be considered free, as the tanks in this area are shallow and unimportant; and the chief one, the Jukkur, irrigates but a small area. A more detailed report and approximate estimate for a supply from this source will shortly follow.

Rachenhalli.

75. To briefly summarize for the three schemes which have been worked out for the supply of the Cantonment and Garrison :—

Summary.

MAGADI ROAD.

Pros.

Most advantageous catchment basin, valley steep and narrow, insuring a rapid and high percentage of run off, the whole catchment being free.

2. Catchment now only cultivated to a small extent, and that with crops but slightly manured.

3. Advantageous site for the formation of the supply reservoir, a deep narrow valley, height of dam to store one year's supply 45 feet above river-bed, area of waterspread at that level 85 acres. Height of dam to store 18 months' supply 54½ feet, area of water-spread at that level 124 acres. A still larger supply could be stored if necessary.

4. Analysis shows the quality of the water from this source to be much purer than any of the others.

5. Constantly flowing stream of limpid water flow, said to continue even in the dryest weather to a small extent.

Cons.

1. Cost of the project and annual working charges.

2. Possible difficulties with the reservoir owing to the amount of silt brought down by floods.

3. *Possible* difficulties in obtaining permission from the Mysore Government to carry out the works as the supply of the Pettah from this source has been talked of; however there should not be great difficulty from this cause as Sankey's tank has been handed over to Mysore.

76. HEBBAL AND NAGAVARA SCHEMES.

Pros.

Smaller initial cost with lower annual cost for working. Distance to sources of supply being less as also heads to be pumped against. These advantages are also in favor of the Hebbal scheme as compared with Nagavara, while there is but little counterbalancing advantage in favor of the latter, as here the compensation for land submerged would be much more costly. The latter tank is now rapidly drying up. Rather than reserve the 5 square miles of free catchment belonging to Hebbal, to supply the Nagavara tank for supply of the town, it would be better to adopt the Hebbal tank as a source of supply and increase its free catchment by taking up some of the tanks above it.

Cons.

1. Water not so pure as that of Magadi Road.

2. Shallow tanks of great water-spread involving the storage of a large volume of water to meet loss by evaporation and leakage.

3. Catchment basins not large enough to furnish required supplies in any but favorable seasons of rain-fall.

4. Catchment basins highly cultivated and manured and generally not favorable to a rapid run off.

5. Cost of compensation for land submerged and deprived of water would be expensive, as land in both localities is valuable.

77. General Summary.—All in favor of Magadi Road. To reserve the free catchment areas would be very expensive. The cost has not been brought into the estimate for each scheme, but has been added, at foot, in the general abstract. The amount for Magadi Road has been made out in detail by the Mysore Revenue Department, for the other schemes approximate values deduced from total areas and average value of the land have been entered.

78. A statement accompanies, showing how the annual working charges have been arrived at. As in previous estimates 15 per cent interest and depreciation has been allowed on the machinery, but only 7 per cent on all other iron work, pipes and fittings etc., and 4 per cent on the balances of the estimates. The entries for establishment should suffice, and in making them out the cost of working the elaborate engines which drive the cotton spinning mills at this place has been looked into. These are worked very inexpensively by a far smaller establishment than had now been allowed for, but even this latter is only about ½ of the present Ulsur establishment where also the cost of firewood is greater than at the cotton mills, the reason assigned being that, the mills are at liberty to make advances to contractors which a Government Department cannot do. At Ulsur works wood fuel has been costing from 217 lbs to 270 lbs per Re. 1. At the cotton Mills, Re. 1 per 316 lbs. 300 lbs per rupee has been taken as the cost, for these calculations, the consumption of wood per hour has been taken as quoted by Messrs Richardson and Cruddas for each engine. Of course, the comparatively antiquated engines and pumps of the Ulsur works could not be as economically managed as the more perfect machines now in the market.

Cost of working.

And in considering the cost of working the schemes under reference, the cost of the present Ulsur supply for the Troops alone (Rs. 16,565 for establishment and working +allowance for interest on first cost, this latter has been calculated to amount to Rs. 31,889, total Rs. *48,454) should be deducted, it represents almost an annual dead loss to Government. If a combined supply to Garrison and Cantonment were carried out, the annual total cost could easily be met by a very low water rate, about Rs. 1 per head of the population who already probably pay as much or more for their present unsatisfactory supply. As far as has been ascertained a water rate would be cheerfully paid.

*Cost for 1,000 gallons Rs. 2½.

SUPPLY SCHEME FOR THE GARRISON ALONE.

The importance and urgency of obtaining a pure and unfailing supply of water for the Garrison, in the event of its not being found possible to carry out a supply scheme for the Garrison and Cantonment combined being recognized, the estimates amounting to Rs. 2,34,130 have been prepared, the comparative statement gives the cost and other particulars side by side with the large schemes. The annual working expenses are estimated at Rs. 20,000, cost per 1,000 gallons being Rs. 0—14—0 against Rs. 2½ per 1000 gallons, cost of the existing Ulsur supply.

Reference No. 4.

2. It is proposed to draw the supply from the same source, as for the combined supply from Magadi road, only in this case a smaller catchment area being required, a point has been selected ¼ of a mile *above* the bridge over the stream at 5¼ miles of the road from Bangalore to Magadi. Above this point the catchment area is 5 square miles, as colored by a pink line of deeper tint, on the Topographical Survey.

3. Taking as laid down, the required supply at †10,000 C. feet per day the tables of capacity and consumption show (evaporation and waste as before, 0·7 feet per month) that for the year's supply of 3·65 M. C. feet 8 M. C. feet must be stored in the reservoir, the height of dam required being 28 feet feet above river bed.

Reference No. 4.

4. The dam is colored pink on the cross section of the vally, the section of the dam for so much of the height from the top to be the same as designed for the large reservoir. The estimate provides for cement right through as it is proposed to surplus over the dam, provision being made for a mass of rough stone in rear.

5. For the reasons set forth in paras 12 to 18 of the report on the combined supply, it is thought that 18 months' supply should here also be stored, also that a supply for the native troops in Garrison should be included. The supply of 10,000 C. feet per day is based on the requirements of the European troops; only a slight addition to the height of the dam would be needed, the engine power and main provided for is capable of pumping up a larger supply.

6. Provision is made for two sets of direct acting compound engines, pumps and boilers, either of them capable of pumping up a week's supply in three days of ten hours, through a 10 inch main.

Engines and Pumps.

7. The size of the main has been calculated as before, a head of 6 feet per mile being allowed, seven days supply pumped up in three days of 10 hours i. e., $\frac{70,000}{3\times10\times.6\times.9}=0{\cdot}648$ C. feet per second, a quantity the 10″ pipe will discharge.

8. The same arrangement of settling ponds, filters and service reservior as for the larger schemes has been estimated for, the service reservoir to hold ten days supply and to be roofed in with brick arches supported by stone pillars and rolled iron beams similar to the one proposed for the larger schemes.

Settling ponds, filters and service Reservoir.

A suitable site will be on the South Parade as shown on the Topographical Survey of the Contonment. Borings show the soil to be a firm red clay with some sand. From the service reservoir the supply can be conveyed to the Infantry Barracks cistern and on by the existing lines of pipe to the Cavalry and Artillery cisterns.

†Over 11,000 Cubic feet per diem have been pumped up from Ulsoor in the dry season.

(a) In drawing up this report, endeavours have been made to make it as concise as possible, consequently nothing has been noted regarding Topographical peculiarities of the country, climate, rainfall, &c. &c,, &c.; quite enough has already been written on these subjects.

Concluding remarks.

Chapter II of Mr. Lee's essay contains a general description of Bangalore, and in the same pamphlet is a diagram showing the rainfall for a series of years. The levels given in the pamphlet are incorrect and the estimates extremely sketchy, and with reference to the notification published with G. O. No. 2810 W. of 20th October 1887 (page iii of Mr. Lee's essay) it may be noted that the essay has not in any way been adopted as the foundation of the Magadi Road scheme as now prepared except so far as indicating the locality and source of supply.

(b). All the estimates which have hitherto been prepared for the water supply of Bangalore, made provision for stand pipes, an obsolete expedient, now hardly ever adopted, the necessary pressure to force the water through the mains is now-a-days always communicated by the engine through the medium of an air vessel.

(c). For the sake of comparison a table is appended, giving the estimated amounts of the Garrison supply estimate as now prepared and that drawn up by the late Captain Romilly for a Garrison supply from the Agram tank.

(d). The projects as now submitted are by no means as complete, particularly as regards plans as the undersigned could have wished; but as time was an object most of the plans are sent just as they have been roughly drawn out in pencil.

(e). The Hessargutta tank on the Arkavati river has been brought forward as a source of supply by Colonel Vibart and has been briefly alluded to in paragraph 73. It is thought that the objection to the impurity of the catchment is not a very serious one; the table of analysis shows the water to be good. There can be no question that a very large volume of water could be impounded in an ordinary year, as per figures given in this office report No. 74 of 26th November 1888. Notwithstanding the greater distance—11 miles from service reservoir site—the level of the tank being higher, the head to be pumped against would be 18 feet less than at Magadi Road. To impound a two years' supply the cost would not probably be much more than at Magadi Road and at the latter locality would be the risk and chances of leakage, attending the construction of a high dam. At Hessargutta the existing tank of a capacity of 91 M. C. feet with its massive old bund would be, as it were, a reliable foundation to start from.

2nd February 1889.

J. C. LARMINIE
Executive Engineer.

Residency Press, Bangalore.—18-2-89.—12.

Bangalore Water Supply.

Comparative statement showing cost and other particulars &c. of the various schemes proposed.

	Magadi Road-Maligal.	Hebbal Tank.	Nagavara.	Garrison Supply.	
Distance from source of supply to service reservoir.	5 miles.	2¼	3	5½ miles.	Net distances.
Head to be pumped against	356	162	186	232 feet.	Includes head allowed to overcome friction in supply main at 6' per mile. Head calculated from level of pumps to delivery level in the settling Ponds. Pumps placed 25' above lowest take-off.
Lowest take-off level	2741·71	2918·0	2897·0	2793·37	
Delivery level in settling ponds	3090·0	3090·0	3090·0	3014·62	
Areas of Reservoirs at F. S. L.	84·76 acres.	361	334·6 acres.	18·22	
Capacities of do at do ...	60·54	123·4	106 M. C. feet.	8·124	Required supply 40 M. C. F.+waste from all sources. For 1, 2 and 3 required supply 40 M. C. F. for Garrison 4 M. C. F.
Total catchment area	9	13	13·6	5	
Free do do	9	5·0	3·6	5	
		ABSTRACT OF ESTIMATES.			
Dam	1,92,740	25,650	30,500	50,000	To store 18 months' supply at Magadi Road add Rs. 77,630.
Engines, Pumps and Boilers	53,000	40,000	44,000	13,000	
Connection with Reservoir	1,000	...	...	...	
Pump Well	12,000	12,000	12,000	6,000	
Engine and Boiler House	5,000	3,000	5,000	2,000	
Chimney	14,000	14,000	14,000	5,000	
Quarters for Establishment	2,57,000	1,15,400	1,51,900	1,12,900	18 inch main for 1, 2 & 3; 10 inch main for Garrison supply.
Supply Main	37,350	37,350	37,350	14,210	
Settling Ponds	36,860	36,860	36,860	7,610	
Filters	53,430	53,430	53,430	21,510	
Service Reservoir	2,29,744	2,29,744	2,29,744	...	
Town distribution	85 acres at Rs. 100.	100 acres at Rs. 100 57 „ at „ 150	200 acres at Rs. 100 50 „ at „ 200	18 acres at Rs. 50	
Compensation for land submerged by Reservoir...	8,500	18,550	30,000	900	
Do for land deprived of water ...	...	Assessment x 10 10,770	10,770	...	Major Kensington states that the land now under Nagavara tank could be supplied by Rachenhalli tank, so no allowance is made. As all the water from Hebbal free catchment would be required for Nagavar Tank, none could be spared for irrigation, so the amount for land deprived of water is also entered against the latter estimate.
Total...	9,02,124	5,98,254	6,55,054	2,34,130	
Annual cost of working	* 91,000	* 61,000	* 65,500	* 20,000	
Cost of water per 1,000 gallons	Rs. 0 5 9	Rs. 0 3 3	Rs. 0 4 3	Rs. 0 1 6	

* Including interest on cost of construction.

J. C. LARMINIE,
Executive Engineer.

No 134 of 25-2-89. 26/1000

To

The Chief Engineer
P.W.D. Madras.

Sir

I have the honor to forward 6 copies of the Reports on Bangalore Water Supply Investigation. No more copies are available.

Please put it very well.

J. C. Lawrence
Executive Engineer
Bangalore Water Supply Inv.

SECRETARY TO GOVERNMENT
26 FEB. 89
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Dated 25-2-89

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