Public Works (1899) Department.

G.O., No. 961 9

DATED 6 Nov 1899.

[Despatch Abstract.]

Kodayar Project, Travancor State.

Pros: Polit: Dept: according to the request of the Resident in Travancor & Cochin to be allowed to send plans and estimates in connection with the —— to the Chief Engineer for Irrigr, headqrs for scrutiny, commd to the latter Officer

Indexed. 11/11

[P. W. 2. 500—27-10-99.]

BACK PAPERS.

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

FURTHER PAPERS.

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

Public Works (1899) Department.

CURRENT No. 8662

From The Political Dept.

N/ *Order* No. 961 Dy 10-11-99

Communicated
to the Chief Engr for
Irrigation

No. 705

Dated 16-10-99

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To
The Chief Engr for I.
Political Dept.

1619
25/10/99

8/10/11/99

W.C.D.

SUBJECT.

According to the request of the Resident in Travancore and Cochin to be allowed to send the plans and estimates of the Kodayar Project to the Chief Engineer for Irrigation at Madras

BACK PAPERS.

No.	Date.

FURTHER PAPERS.

No.	Date.

[53]
21-7-09.

Political Department.

GOVERNMENT OF MADRAS.

PROCEEDINGS OF THE MADRAS GOVERNMENT.

READ the following paper:—

From the Resident in Travancore and Cochin, Reference on C. No. 2939, dated 5th October 1899:-

When Mr. Jacob was Chief Engineer of the Travancore State work was begun upon a scheme known as the Kodayar Project. This is a scheme to throw a dam across a mountain stream and to form a reservoir at a point which is Lat 8°.27'N. Long 77°.22'E. on atlas sheet No. 65.

2. Mr. Jopp, the present Chief Engineer, has completed the estimates for this scheme. In round figures eleven lakhs of rupees have been spent and sixteen lakhs more are required, or a total of twenty seven lakhs.

3. The Revenue officers have now finished their investigation of the lands which will be commanded by this reservoir. The return is expected to be three lakhs, so that this work may bring in ten per cent upon the outlay.

4. Mr. Jopp presses for early sanction of his estimates in order that he may go on with the work. The Darbar is disposed to grant sanction, but considers it desirable that the views of Mr. Jopp may be corroborated by some independent opinion. I may mention here that Mr. Nicholson, the late Resident, thought very well of the scheme.

5. It appears to me that, as eleven lakhs have been spent, the State is committed to the scheme and the sixteen lakhs for which Mr. Jopp asks must be sanctioned. But as the Travancore Darbar has expressed a desire for another opinion I have the honour to soli-

permission

permission to send the plans and estimates to the Chief Engineer for Irrigation at Madras for scrutiny and for any discussion that may be found necessary.

6. The plans and estimates, which are very bulky, were sent to me by the Diwan with a demi-official letter, which gives a very lucid history of the scheme. I have the honour to forward a copy of this demi-official letter for the information of Government and also to send a copy of the Chief Engineer's printed memorandum.

Order:-No. 705 dated 16th October 1899.

The Governor in Council is pleased to accede to the request contained in paragraph 5 of the letter read above.

(True extract)

Chief Secretary.

16.10.99

To

The Resident in Travancore and Cochin.

" Public Works Department (Irrigation)

I. GENERAL AND FINANCIAL.

i. Personal.

Revision of Project found necessary.

Although this Project has now been in progress for over 3 years, it is only recently that definitive details of the Scheme have been worked out. The original Scheme was submitted in a very incomplete state.

*April 1896.

Within a few days of my arrival in Travancore,* at the request of the Dewan, I inspected and reported on the Project and brought to notice, as far as I was able in such a short time, the chief defects in the Scheme as designed and being carried out. After some months of further acquaintance, still more serious defects were ascertained and pointed out and the sanction* of Government obtained to a revision of the Project.

*October 1896.

Responsibility.

I had hoped that this report might have been kept free from any personal element. Unfortunately, as there is an impression that this revision might and should have been effected by me long ago, and that there is in consequence some blame attached to me for the work progressing without a formal revised estimate; and further as there is much in the original Scheme and in the original designs, which I have had unavoidably to adopt, but of which I entirely disapprove and for which no responsibility or blame should attach to me hereafter, it is necessary that I should clearly define what part I have had in connection with the Project, and what my responsibilities are.

I admit my responsibility for all professional designs and details of the Project as now revised and submitted to Government for sanction, except such portions of it as are the designs of my predecessor, or are the unavoidable sequence of his designs.

I may illustrate these remarks by a few instances—I must disclaim responsibility for the figures showing areas available for new wet cultivation in the different tracts, given by Mr. Thanu Pillai in his Memo, received with the Dewan's demi-official letter dated 7th January 1895, and on which the original Project was evolved.

So also I must be free from responsibility for any of the results, of aligning the left bank channel making it fall into the Paralayaur above the Puthen instead of above the Pandian dam; of the details in design of the left bank channel such as its discharging capacity, its inside and outside slopes, its rate of inclination, its enormously high embankments ~~&c.~~ the capacity of the Reservoir &c.

I must also disclaim responsibility for any errors or actual losses, owing to work having been started before full preliminary investigations were made, and a carefully thought out Scheme prepared and sanctioned.

Investigations necessary for the project.

And this brings me back to my remark that dissatisfaction has been felt, owing to the work having been in progress for the past two and a half years without the revised scheme having been submitted for sanction.

It is possible that until now the Government has not been aware what the working up of a Project of this sort involves.

It may have been thought that nothing but the calculation of so many feet of masonry work or earthwork was all that was needed. But this is far from the case; a large quantity of local information has first to be collected – such as results of numerous trial pits, rainfall registers, contours, areas available for cultivation, characteristics of soils, alignment of channels, materials of construction, facilities for labour, &c. &c. before the practicability of a project can be determined and before the designing of engineering details and the estimating may be proceeded with.

Such a work is usually considered amply sufficient to engage the undivided attention of one or more Engineers. It has fallen entirely on my shoulders in addition to my duties as Chief Engineer.

I would ask a reference to the official records, to ascertain what sort of preliminary study of the aspects of the Project was made prior to the submission of the original Estimate. As yet I have found nothing bearing on such a subject. The Project was submitted in a very crude and incomplete form and it has rested with me to make the necessary investigation for the preparation of an intelligible revised project *ab initio*, since I took over charge of the works.

The Government should consider what the results of carrying out so ill-digested a project as the original might have been.

I trust that the Government after reading this report will approve of the Project having been carefully investigated, and will not think the time has been ill-spent, or that there has been any delay in submitting the revised estimate.

Sanction not exceeded.

No one could have felt the want of a definite scheme, and fully worked out designs and estimates more than I. The greatest difficulty and anxiety has been felt in carrying on the work, so as to throw no hindrance in the way of the full development of the Project hereafter, and at the same time not exceed the exact partial arrangement as originally sanctioned by Government.

* and this with the sanction of Government.

Except that the excavations for the main dam have been taken out to the full width and length required for a dam of the height shown in the revised Estimate *, no work has been undertaken beyond the extent of the original sanctioned Estimate.

The Government is, therefore, in no more insecure position in regard to the Project now, owing to any action that I have taken, than they were some $2\frac{1}{2}$ years ago, when the works came under my control; and it may elect to carry out the work to the extent of the original sanction only or to the extent shewn by me in the revised Estimate.

ii. Scope of revised Project.

Revised Estimate.

A perusal of the revised Estimate and comparative statement accompanying this report will clearly shew the original Project, the Project as now revised, and the additional works now contemplated and which require sanction.

It will be at once seen that the original Project provided only for forming a reservoir and cutting a channel $10\frac{3}{4}$ miles in length up to the Paralayaur. Now although it professed to accomplish the irrigation of 15,000 acres of fresh land, and to aid the 23,000 acres of existing cultivation, it made no provision whatever for channels to convey the water to those fresh lands and in this respect was only a first section of the project. In short the Project, as it was originally sanctioned, could possibly only have ministered to the 23,000 acres of old cultivation.

The revised Project provides for a reservoir of greater capacity and of extended utility to a larger area of country, and includes the cost of the new channels to convey the water to the fields.

Estimates for distribution channels.

I regret that the estimates and plans for these additional works are not in a sufficiently advanced state to be submitted with this report.

I have, however, been able to enter figures in the revised estimate which, I believe, will prove fairly accurate.

All of the proposed channels have been investigated and located, except the Attur channel, a comparatively small branch, and a short length of the Tovala channel about which there is no difficulty. All of the other channels are practically finished as far as field work goes and a considerable amount of plan drawing and estimating has already been done. The details of the channels are given in the body of the report.

Determination of areas to be served.

A tedious, yet important duty, that remains in connection with them, is for the Revenue Department; and that is, to estimate the areas that will probably be irrigated. This Department has nearly finished the maps shewing the areas actually commanded, and for the purposes of this report, has estimated the area that may be irrigated, but the figures are Engineer's figures, which the Government should get checked by the Revenue Department.

COMPARATIVE STATEMENT.

Kothayaur Irrigation Project.

Abstract of original and revised Estimates, with explanations of differences.

Item No.	Sub-heads of estimate.	Original Estimate. Cost.	Revised Estimate. Cost.	Saving.	Excess.
1	Main Dam	2,53,782	7,24,500	...	4,70,718
2	Head Sluices	18,808	1,10,500	...	91,692
3	Under Sluices	Nil	25,800	...	25,800
4	Surplus Weirs	Nil	45,200	...	45,200
5	Left Bank Channel	4,80,405	5,84,700	...	1,04,295
6	Tiruvancode Channel	Nil	2,27,000	...	2,27,000
7	Erattakarai Channel	Nil	15,000	...	15,000
8	Anandanar Extension	Nil	10,000	...	10,000
9	Tovala Channel	Nil	3,50,000	...	3,50,000
10	Parakai Channel	Nil	5,000	...	5,000
11	Right Bank Channel	Nil	3,64,400	...	3,64,400
12	Road deviations	9,955	14,800	...	4,845
13	Land compensation	Nil	70,000	...	70,000
14	Bangalows and Camps	11,000	55,000	...	44,000
15	Tools and Plant	16,500	27,000	...	10,500
16	Preliminary Expenses	4,400	25,300	...	20,900
17	Miscellaneous and Contingencies ...	...	45,800	...	45,800
	Total.....	7,94,850	27,00,000	...	19,05,150

Explanation of Excesses or Savings—

1. The excess is due to the height of the dam being increased in order to impound a greater quantity of water.
2. The original estimate provided only a lump sum for one head sluice which was quite inadequate. The revised estimate provides for head sluices to the Left Bank and the Right Bank Channels—hence the excess.
3. No under sluices provided in the original estimate.
4. The original estimate allowed the surplus water to flow over a portion of the dam; the revised estimate provides separate escapes.
5. The excess on this item is due chiefly to the inaccuracies of the original estimate, lump sums only in many instances having been provided; also due to alterations of bad designs found necessary after investigation.

6 to 11. No provision in the original estimate.

12. Excess due to a road deviation, found necessary in the 7th mile.
13. No provision in the original estimate.

14 to 16. The original provision was totally inadequate.

17. No provision in original estimate.

iii. Financial.

Data.

On the basis of these figures the following statements have been prepared shewing the financial aspects of the Project as revised. These have no pretensions to great accuracy owing to doubt in respect to the area that will ultimately be taken up, to difficulty in ascertaining what returns the newly fed lands will bring in to Government in the shape of water rates, and to the complicated system of land tenures.

In preparing the statements it has been assumed, that a uniform return of Rs. 5 per acre will be obtained from 40,000 acres taking 10 years to come under cultivation.

The cost of annual maintenance has been estimated at 8 annas per acre; at present in existing channels it is much less but the system is inefficient.

Rapid execution recommended.

As I wish to bring forward prominently, the desirability of pushing on with the execution of the works as energetically as possible, if the revised scheme obtains sanction of Government, I have had the statements drawn up to shew the financial aspects of the Project, as it would be affected by the length of time taken in carrying it to completion.

The first statement shews the capital cost of the Project on account of direct charges alone.

The subsequent statements shew the progressive direct and indirect charges and the progressive revenue receipts, assuming, first that 3 years, and then that 4 years, are taken to complete the Project. It will be observed that in the first case the returns will be at the rate of 8·4 per cent on the capital expenditure, and in the second case 8·2 per cent.

Further by delaying the completion of the work by one year, the Government will lose the benefit of the earlier revenue return and will incur the further enhancement of capital cost by accrual of interest; these two together would amount to about three-quarters of a lac of rupees.

From the statements it may be ascertained what annual expenditure should be incurred to ensure completion in either term of years.

But before turning to the tables it should be noted, that no credit has been taken for sale proceeds of large areas of waste land that will accrue to Government. As these sales would be brought about solely by the supply of water from the channels, they should fairly be credited to the Project.

The inclusion of the Right Bank channel in the revised Project has been opposed by some few persons, from ignorance of the necessities of the area or from other motives. It is a sufficient reply to their objections to say that the sale of waste lands under that channel will alone more than pay for the costs of its construction.

I have it on good authority that it will be a moderate estimate to assume that, at least 5,000 acres of waste will be sold for cultivation under the system; and that an average rate of Rs. 150 per acre will be realised. If the average rate be taken as low as Rs. 100 per acre, a sum amounting to 5 lacs of rupees would be realised; and this being solely due to the Project may fairly be shewn as a deduction from the capital expenditure. Were credit to be taken on this account, in the subsequent calculations, the net returns to the Government on the undertaking would rise to over 10 per cent.

The importance of the sale of these waste lands on the financial aspect of the Project was so fully realised by the late Dewan, Mr. Shungrasoobier, that he issued orders for the settlement and registration of lands in the taluks likely to be benefitted by the Project to be deferred for the present.

As a matter that seriously affects the financial success of the undertaking, it requires the early and earnest consideration of the Government.

TABLE I.—KOTHAYAUR IRRIGATION PROJECT.

Revised Abstract of Estimate,

Showing direct approximate charges to capital on account of cost of works.

Number.	Particulars.	Amount.
1	Main dam	7,24,500
2	Head sluices	1,10,500
3	Under sluices	25,800
4	Surplus weirs	45,200
5	Left Bank channel	5,84,700
6	Tiruvancode channel	2,27,000
7	Erattacarai channel	15,000
8	Anandanar extension	10,000
9	Tovala channel	3,50,000
10	Parakai channel	5,000
11	Right bank channel	3,64,400
12	Road deviations	14,800
13	Land compensation	70,000
14	Bungalows and camps	55,000
15	Tools and plant	27,000
16	Preliminary expenses	25,300
17	Miscellaneous and contingencies ...	45,800
	Total.....	27,00,000

TABLE II (*a.*)

Estimated progressive direct debits to capital account up to date of completion of works.
Assuming completion in 4 years from date.

Year.	Works.	Establishment and tools and plant at 10 per cent.	Total.
To end of 1073	7,00,000	70,000	7,70,000
1074	5,00,000	50,000	5,50,000
1075	5,00,000	50,000	5,50,000
1076	5,00,000	50,000	5,50,000
1077	5,00,000	50,000	5,50,000
Total ...	27,00,000	2,70,000	29,70,000

TABLE II (*b.*)

The net estimated progressive direct and indirect debits to capital account up to date of completion.
Assuming completion in 4 years from date.

Year.	Debits to capital.	Sum on which interest is calculated.			Simple interest at 3 per cent on (5).
		Debits to end of previous year.	Half debits during year.	Total.	
1	2	3	4	5	6
To end of 1073	7,70,000	...	...	...	...
1074	5,50,000	7,70,000	2,75,000	10,45,000	31,350
1075	5,50,000	13,20,000	2,75,000	15,95,000	47,850
1076	5,50,000	18,70,000	2,75,000	21,45,000	64,350
1077	5,50,000	24,20,000	2,75,000	26,95,000	80,850
Total ...	29,70,000	...	...	74,80,000	2,24,400
		Total debits to capital and interest...		...	31,94,400
		Deduct Receipts in 1076 and 1077			1,48,100
		Total Net debits to capital and interest at end of 1077			30,46,300

TABLE II (*c.*)

Estimate of Revenue Receipts and percentage return on capital assuming completion in 4 years.

Year.	Area irrigated by Project at end of year.	Revenue due to works at Rs. 5 per acre.	Add non-remission on existing lands.	Total gross earnings.	Deduct maintenance charges at 8 ans. per acre.	Total net earnings.	Percentage on outlay.
			*				(1)
1076	400	2,000	70,000	72,000	200	71,800	3·3
							(2)
1077	1,400	7,000	70,000	77,000	700	76,300	2·7
							(3)
1078	5,400	27,000	70,000	97,000	2,700	94,300	3·1
1079	9,400	47,000	70,000	1,17,000	4,700	1,62,300	3·6
1080	13,400	67,000	70,000	1,37,000	6,700	1,30,300	4·3
1081	17,400	87,000	70,000	1,57,000	8,700	1,48,300	4·9
1082	21,400	1,07,000	70,000	1,77,000	10,700	1,66,300	5·5
1083	25,400	1,27,000	70,000	1,97,000	12,700	1,84,300	6·0
1084	29,400	1,47,000	70,000	2,17,000	14,700	2,02,300	6·6
1085	33,400	1,67,000	70,000	2,37,000	16,700	2,20,300	7·2
1086	37,000	1,85,000	70,000	2,55,000	18,500	2,36,500	7·8
1087	40,000	2,00,000	70,000	2,70,000	20,000	2,50,300	8

* These figures it is understood represent an average of remissions in the Nanjenaud and Edanaud. To this should be added the remissions on the lands included in the project in the Vilavankod and Neyyattinkara Taluks which figures I was not able to obtain.

Note—Table is based on assumption that water will be utilised as soon as made available 1075—1076 before actual completion of work.

(1) Calculated
(2) Calculate
(3) And do

TABLE III (*a.*)

Estimated progressive direct debits to capital account up to date of completion of works.
Assuming completion in 3 years from date.

Year.	Works.	Establishment and tools and plant at 10 o/o.	Total.
To end of 1073 ...	7,00,000	70,000	7,70,000
1074 ...	7,00,000	70,000	7,70,000
1075 ...	6,50,000	65,000	7,15,000
1076 ...	6,50,000	65,000	7,15,000
Total ..	27,00,000	2,70,000	29,70,000

TABLE III (*b.*)

The net estimated progressive direct and indirect debits to capital account up to date of completion.
Assuming completion in 3 years.

Year.	Debits to capital.	Sum on which interest calculated.			Simple interest at 3 per cent on (5)
		Debits to end of previous year.	Half debits during year.	Total.	
1	2	3	4	5	6
To end of 1073 ...	7,70,000	...	...	...	...
1074 ...	7,70,000	7,70,000	3,85,000	11,55,000	34,650
1075 ...	7,15,000	15,40,000	3,57,500	18,97,500	56,925
1076 ...	7,15,000	22,55,000	3,57,500	26,12,500	78,375
					1,69,950
Total ...	29,70,000				31,39,950
		Total Gross debits to capital and interest.			
		Deduct receipts in 1075 and 1076			1,48,100
		Total net debits to capital and interest at end of 1076			29,91,850

TABLE III (*c.*)

Estimate of Revenue receipts and percentage return on capital.
Assuming completion in 3 years.

Year.	Area irrigated by project at end of year.	Revenue due to works at 5 Rs. per acre.	Add non-remission on existing lands.	Total gross earnings.	Deduct maintenance charges at 8 ans. per acre.	Total net earnings.	Percentage on outlay.
							(1)
1075	400	2,000	70,000	72,000	200	71,800	3·8
							(2)
1076	1,400	7,000	70,000	77,000	700	76,300	2·9
1077	5,400	27,000	70,000	97,000	2,700	94,300	3·2
1078	9,400	47,000	70,000	1,17,000	4,700	1,12,300	3·8
1079	13,400	67,000	70,000	1,37,000	6,700	1,30,300	4·4
1080	17,400	87,000	70,000	1,57,000	8,700	1,48,300	5·0
1081	21,400	1,07,000	70,000	1,77,000	10,700	1,66,300	5·6
1082	25,400	1,27,000	70,000	1,97,000	12,700	1,84,300	6·2
1083	29,400	1,47,000	70,000	2,17,000	14,700	2,02,300	6·8
1084	33,400	1,67,000	70,000	2,37,000	16,700	2,20,300	7·4
1085	37,000	1,85,000	70,000	2,55,000	18,500	2,36,500	7·9
1086	40,000	2,00,000	70,000	2,70,000	20,000	2,50,000	8·4

...on the assumption that water will ...on as made available (1075–76) ...orks.

(1) Calculated on an outlay of about ... 19,00,000
(2) Do. 26,00,000
(3) and downwards calculated on an outlay ... 30,00,000

ermission to send the plans and estimates to

II. MAIN FEATURES OF PROJECT.

i Historical.

Localities suitable for irrigation.

The most considerable area of land, that exists in Travancore for the successful cultivation of rice, is in the southern tracts.

These areas are locally known as the Nanjenaud and the Edanaud.

In the Edanaud, the irrigated crops are almost entirely dependent on the artificial supply brought to them by the Palpanabhapuram Puthenaur Channel, which takes off from the Paralyaur above the Puthen Dam. So also the Nanjenaud is chiefly dependent on the artificial supply brought to it by the Pandian channel, which takes off from the Paralyaur above the Pandian Dam. But a considerable area is also dependent on the rain fall in the Nanjenaud basin itself, (chiefly in the hilly tracts) which flows to the fields in channels taking off from the Thadavi, Olakkarivi, Alathorai, Poigai, and Vembamuli.

Deficient supply of water.

As the supply in these sources is not perennial, during the season of rains and flood the water is led into many small reservoirs or tanks, whence it is drawn, as occasion may require, on to the fields. The capacity of these tanks is, for the most part, very limited, so that they have to be replenished very frequently during a season.

There are many defects inherent in this system, which need not be entered into here in detail, but which not only render the successful rearing of crops very precarious, but precludes the possibility of fully or efficiently utilising the water that actually is available.

Unutilised sources of supply.

This irregularity of supply and the knowledge of the existence of a large area of fertile land suitable for wet cultivation, were water only procurable, have always kept prominently in the foreground the desirability of devising some scheme, not only for improving the irrigation system and so increasing the duty of the water, but also for supplementing the existing sources and so enabling the further area of unirrigated land to be brought into wet cultivation. And, from a very distant date, several schemes have been investigated, having this object in view.

The Kothayaur.

The example set by the constructors of the ancient works on the Paralyaur, from which such substantial benefits were being derived by the Nanjenaud and Edanaud, very naturally directed attention to investigation of the possibility of a similar scheme on the neighbouring river, the Kothayaur.

Such a scheme must have appeared the more desirable, knowing the more constant, perennial flow of that river, and therefore, its superior value for irrigation purposes, to either the Palayaur or Paralyaur.

Its catchment basin.

For although the catchment areas of the Palayaur, the Paralyaur and the Kothayaur are all contiguous, their physical characteristics differ considerably.

As regards the Palayaur it is only in the hilly tracts of the catchment (vide map No. I.) a narrow fringe on the north eastern side of the basin, and a few isolated hills about the north-western, that any appreciable quantity of rain falls during the south-west monsoon. In the lower flatter tracts, there is but little rain until the period of the north-east monsoon, which indeed is often, not only useless, but actually destructive to crops.

As compared with that of the Paralayaur

On the other hand, the Paralyaur and the Kothayaur carry off drainage water from contiguous areas of hilly country lying along the eastern boundary of Travancore. In the extreme south of these hills, the rainfall is comparatively small, perhaps only some 30 inches in a year, but as one proceeds northwards, it very rapidly increases to 200 inches in some localities* in the year. In the south, the whole rainfall occurs in a comparatively few months, whereas towards the north, it becomes very rapidly more continuous; in fact, in the Kothayaur catchment basin, there is not a month of the year without a fair fall of rain; moreover, its catchment area above Pachiparai is said to be about 90 square miles, while

*Augusteermalai and other high peaks.

that of the Paralyaur above the Pandian dam is only 60 square miles: the Kothayaur thus being very obviously a more valuable source than the Paralyaur for irrigation purposes.

The ancient works on the Paralyaur indicated above, consist of two masonry dams, known as the Pandian, and Puthen dams or anicuts, which divert the water and conduct it across the ridge, or watershed, into the Nanjenaud and Edanaud valleys respectively (vide map No. 1.) In course of time, the demands for water exceeded this supply, and it was natural that attention should be attracted towards the solution of the problem of diverting the Kothayaur water also, in a similar manner, and for similar purposes.

Various schemes for utilising the Kothayaur.

An actual attempt was made to do this early in the present century. There is nothing on record on the subject, but the remains of a masonry dam at a place known as Kakachel, and several miles of channel now overgrown with jungle, prove the fact, that this abortive scheme probably failed only from a want of proper investigation and engineering skill.

The various investigations that were subsequently undertaken in this direction may be briefly referred to.

The first was about 1837, and continued in various phases until 1852, when it appears to have been finally abandoned as impracticable.

Again, in 1869, it was brought forward by Dewan Madhava Row, but no practical result ensued.

In 1877, Dewan Nanoo Pillay re-opened the subject, and the first intelligible scheme, that is on record, was for a dam across the river, and a channel $12\frac{1}{4}$ miles long to divert the water to the Paralyaur. The estimate amounting to $4\frac{3}{4}$ lacs was obviously far too low.

But before the Government would commit themselves to such an undertaking they considered it advisable to take the advice of an expert. The services of Major Mead R. E. were therefore called in. This officer pronounced the scheme premature, and advised the Government to first undertake the improvements of the existing works and channels of the then existing irrigation system. The Government accepted this advice; and it was not until the completion of these improvements in 1885 that attention was again directed to the Kothayaur.

The first officer who then dealt with it was Mr. Horsley. He condemned the scheme and substituted an entirely new one of his own. It provided, at a cost of about 19 lacs, to construct a number of comparatively small reservoirs in the Nanjenaud basin for merely supplementing the supply, but not increasing the existing irrigated area in the Nanjenaud, and for pumping the water of the Maycode Lake by machinery into the Palpanabhapuram Puthenaur channel for supplementing the Edanaud supply.

The defects of his scheme were obvious both from practical and financial standpoints. The late Dewan Mr. Shungrasoobyer, being impressed with the conviction, that the Kothayaur presented very favourable possibilities and with the urgent need to take action without further delay, instructed Mr. Walch, then Chief Engineer, to review Mr. Horsley's scheme and advise the Government.

Scheme eventually adopted

Mr. Walch's report being entirely in favour of a Kothayaur scheme, Government called for the necessary plans and estimates. These were completed by the late Chief Engineer, Mr. Jacob, and work was actually started in 1895.

In all the schemes that were discussed until this time, the immediate idea was a mere diversion of the Kothayaur water. Mr. Jacob's went somewhat further than this, and professed the formation of a reservoir to impound a quantity of water, sufficient not only to supplement the existing precarious supply to the 23,000 acres of the Nanjenaud and Edanaud, but also, to supply water for 15,000 acres of fresh land. This estimate amounting to 8 lacs, was insufficient to accomplish the end it proposed.

Reasons for revising the scheme.

After the works were started, it was pointed out that there was a very much larger area than 15,000 acres which could be profitably cultivated, if only water were made available, and that, as the Kothayaur was capable of supplying this water, it was thought advisable to revise Mr. Jacob's estimate. This revision places the scheme in a much higher position of utility to the country. Although the estimated cost is considerably more, yet the financial return on the outlay is anticipated to be in a higher ratio than could have been possible under Mr. Jacob's scheme.

ii. Leading Engineering Features.

The leading features of the revised project from an engineering standpoint may be briefly described as follows:—

The river will be crossed by a masonry dam about 115 feet high at its highest point in the bed of river, and 1,525 feet in length along its crest This will form a Reservoir covering an area of about 7 square miles.

To permit operations in the deep bed of the river at the dam site it is necessary to make some arrangement for diverting the water.

At a suitable spot, about a quarter of a mile up the river above the main dam site, a masonry dam 35 feet high is designed to be built, to divert the river along a channel on the left bank, down to a point below the main dam site.

On each flank of the main dam, head sluices are to be constructed, to regulate the supply of water to the channels. They will be capable of drawing off water to a depth of 45 feet below the full supply level in the Reservoir and it is calculated that 4,480 millions of c. ft. of water will thus be impounded, and be available for passing down the channels.

Left bank channel.

The channel taking off on the left flank will tail into the Paralyaur just above the Puthen Dam on its right bank; the water will flow across to the left bank, and will there enter the existing offtake to the Palpanabhapuram Puthenaur and Pandian channels and thence will proceed to the Edanaud and Nanjenaud.

A new channel will branch off from the Palpanabhapuram Puthenaur at ~~11~~ $5\frac{1}{2}$ miles and proceed via Tiruvancode into the Eraniel taluk.

Another small branch will take off at $16\frac{3}{4}$ miles.

In the Nanjenaud, extensions of the Anandanaur, and the Parakai are contemplated, as also an entirely new high level channel taking off from the Pandian channel at 1 mile 3,180 ft. and proceeding towards Tovala as far as Variyoor.

Rihgt bank channel.

The channel taking off on the right flank will find its way to Parachalai in the Neyyattinkara taluk and by means of distributaries irrigate lands in the Vilavankod and Neyyattinkara taluks.

iii. Area to be served.

Situation and extent.

The Project as now revised contemplates the irrigation of 40,000 acres of fresh land for two crops, and to aid 25,550 acres of existing lands in months of scarcity.

The locality of the land to be served may be roughly comprehended from drawing No. 1.

The following tabular statement will shew in detail their position and description:—

Situations of cultivation.	Lands to be newly brought under wet cultivation.			Pre-existing wet cultivation to be aided.	Total ultimate wet cultivation.
	Land already precariously cultivated i. e. Rain-fed Acres.	Uncultivated Perambokú and other dry lands. Acres.	Total. Acres.	Acres	New and old ass[illegible]
Nanjenaud	3,100	6,900	10,000		
Edanaud	4,960	8,260	13,220		
Parachalai	7,000	9,780	16,780		
Total of each description.	15,060	24,940	[illegible]		

[illegible] south, whereas towards [illegible] act, in the Kothayaur [illegible] a fair fall of rain; more- [illegible] oe about 90 square miles, while

The 15,060 acres of precariously rain-fed lands are in every way suitable and ready to receive the irrigation water at present; of the 24,940 acres to be newly irrigated, about 20,840 acres are situate on nearly level sites, and about 4,100 acres are on slopes which require terracing.

Probable time required for conversion to wet.

It must not be imagined that so large an area as this will be opened up at once.

The process of converting dry or waste land into wet cultivation must always be slow; and it must not be put out of sight that although the land is, as far as soil goes, quite suitable for paddy cultivation and the profits would probably be considerable, yet it is sparsely populated and some of it is situated on the slopes of ridges which require terracing. Hence its development will require capital and at the start may be slow.

That these difficulties, however, can and will be overcome when the profits to be made are clearly seen, can be tested for oneself by inspecting the yellas and their adjoining slopes in the Neyyattinkara taluk and elsewhere where cultivation is being carried on.

The system of terracing is in places already worked out on an extensive scale and it would appear that valley slopes with grades less steep than 1 in 12 to 1 in 10 or even steeper can easily be terraced and cultivated without great outlay.

Moreover the Sircar tax on land such as this averages as low as Rs. 1–2–8 as against Rs. 1–9–8 in Malabar. Assuming it to be classed as wet, the tax would average Rs. 2 per acre against average rates in British India varying from Rs. 3 in Malabar to as much as Rs. 9 in Tinnevelly.

Here also no extraneous taxes exist such as road and village cesses so that there seems fair prospect of the ultimate area being taken up within 10 years from the date of completion of the head works.

Present condition of the lands.

The present state of much of the land that it is now proposed to bring under the influence of the reservoir is such that a scanty crop of gram or tapioca can be reared only with the greatest risks owing to possible failure of rain. The soil, however, is as a rule very suitable for paddy cultivation, leaf manure is plentiful and cheap and with a perennial and certain supply of water there should be little doubt of a double crop of certainly average yield.

In the Eraniel, Neyyattinkara and Vilavankod taluks wherever cultivation has hitherto been attempted, the yield is said to be good, whenever the rainfall is sufficient and seasonable. But the lands are entirely dependent on rainfall, there are no tanks or irrigation works, and the consequence is, sometimes entire failure of crop, frequently an indifferent yield; this is especially the case in portions that lie to the west of the Main Southern road.

Soil.

In these tracts the rainfall is light, varying from 35 to 45 inches only in the year. Vide map No. 1 and the rainfall registers, in the Appendix No. 1.

The quality of the soil is for the most part good and will be briefly described. In the Nanjenaud it varies considerably according to position.

(1) That portion that will be supplied from the first miles of the Tovala channel as far as Seethapal consists of reddish clayey soil mixed with particles of disintegrated rock and with vegetable mould. Laterite soil appears only in two places. It is very suitable for paddy, as is evidenced by land recently brought into cultivation producing good crops without any necessity for manuring beyond the usual leaf manure.

In the next 6 miles of the channel from Seethapal to Tovala the soil contains [illegible] There are considerable deposits of limestone in the subsoil and the water than this, river known as the Uparodai is also impregnated with lime &c. and is water, sufficient [illegible] water for cultivation. If supplied with good water from the 23,000 acres of the Nanj[illegible] full crops will be obtained but there will be a moderate acres of fresh land. This es[illegible] as is testified by such lands cultivated under the plish the end it proposed.

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From Tovala hill spur as far as Mylady gap the soil is a reddish brown earth similar to that on which cotton is grown in Tinnevelly.

From Mylady gap to the end of the channel the land to be supplied varies from reddish brown at Mahadanapuram to light black sandy earth at Variyoor. This latter soil is said to give a better yield than the reddish brown.

(2) Anandanaur extension and Parakai channel will supply a red rather sandy soil, hard when dry but working into slush when wet. It requires a good deal of water for wet cultivation. The land is flat.

(3) The Eratakarai channel will command land composed of dark red soil somewhat like a rather sandy laterite.

(4) The Tiruvancode channel in its main line is to supply a soil that is similar in its more elevated localities to the Eratakarai channel soil but near to the sea it is more sandy. The sub-soil consists of moderately hard laterite. In its Neyur branch the land served is flatter. The soil is a lighter red and with a less admixture of laterite.

(5) The right bank channel in its first section of 10 miles commads a country consisting of rather retentive clay with its top layers mixed with much vegetable mould. Thence as far as the southern road the soil is a red gravelly laterite on the slopes and a darker coloured loamy soil in the valleys.

Between the southern road and the sea, the country changes into a looser soil with particles of drift sand.

The new lands have excellent facilities for drainage.

iv. Capabilities of the Reservoir.

To prove that the Kothayar can supply and the Reservoir retain, such a quantity of water as these areas will demand, the following table is drawn out.

It may be remarked in connection with it that in calculating the river discharge the average of four years has been taken of which three were distinctly dry years in order to be on the safe side.

Month.	Quantity received in the Pachiparai reservoir in millions of c. yards.	Quantity required to be drawn off for irrigation in millions of c. yards.	Loss by evaporation and absorption in millions of c. yards.	Quantity left in the Reservoir at end of each month in millions of c. yards.	Quantity running to waste in millions of c. yards.	Remarks.
June	162·22	116·52	5·42	179·60	,,	This table is prepared on the following assumptions:
July	187·72	89·98	5·96	Full 193·37	88·22	(*a*) That the duty of water will be 1 c. foot per second to 45 acres or 15,000 c. yards for 2 crops per annum.
August	167·00	89·98	5.78	Full 193·37	71·24	(*b*) That demand will be made on the reservoir as follows:—
September... ..	70.84	84·03	6·87	173·31	,,	(1) From May to January inclusive by 40,000 acres of newly cultivated land (2 crops full supply).
October	126·34	84·03	4·88	Full 193·37	17·57	(2) From May to August inclusive by 2,100 acres of existing wet cultivation for Kanny crop only.
November	157·24	84·03	4·88	Full 193·37	68·33	(3) For part of May, June, December and January by 25,550 acres of existing cultivation to supplement their supply at 10 p. c. of full supply.
December	83·13	112·04	2·35	162·11	,,	(*c*) The capacity of the reservoir at the R. L. + 299·00 is 193·37 millions of cubic yards.
January (20 days) ...	40·00	74·69	4·34	123·08	,,	(*d*) That evaporation and absorption will occur monthly as follows—the rates being those established by a series of observations at the Red Hills tank, Madras, which here will at least not be exceeded.
February	16·92	,,	4·34	135·66	,,	
March	9·24	,,	4·70	140·20	,,	
April	13·90	,,	5·42	148·68	,,	
May (10 days) ...	36·20	38·85	6·69	139·36	,,	

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Inches per diem.	0·24	0·24	0·26	0·30	0·37	0·30	0·33	0·32	0·38	0·27	0·27	0·13

Duty of water assumed.

It should be noted that a very low duty has been assigned to the water, while, as a matter of fact, the duty is likely, in a humid climate such as this to be a high one and in forming an opinion as to the capabilities of the Project this is a point of some weight. It is affected by various considerations such as the efficiency of regulation, the rate of evaporation, the porosity of the soil, the quantity and period of local rainfall, and the local methods of cultivation.

As to these, the efficiency of regulation, can, on a new system, be ensured with fair certainty.

The rate of evaporation is as already stated lower on this coast than on the East coast. It has been ascertained from the records of the Government Observatory at Trivandrum that the mean rate from 6 years' observations is only 0·242 inch per diem here against 0·284 at Madras.

In tracts of Eraniel and Tovala and part of Neyyattinkara, the humidity is not so great, and strong winds are prevalent so that the rate of evaporation will be greater than at Trivandrum but at all interior tracts it will be at least the same.

Porosity of the soil. In the Nanjenaud it is fairly clayey and retentive but in Neyyattinkara and Eraniel it is rather porous on the slopes but less so at the bottom of the valleys.

It should, however, in this connection, be borne in mind, that land on which rice is grown, although at first it may be rather porous, soon changes its original character very considerably. Owing to the manner in which such cultivation is conducted, the surface soil of the fields being ploughed up and worked into a state of slush, the sub-soil becomes, as it were, staunched or puddled so that, although originally of a porous, it assumes a retentive, nature.

The periods of local rainfall would be favourable in the Neyyattinkara and Eraniel taluks.

Local methods of cultivation.

The local methods of cultivation, are peculiar to this part of Travancore and merit a detailed description.

Two kinds of rice are generally grown in the South, the first common red rice (Chamba) and the second superior white grained rice (Varsirmindan).

The first is usually sown about the 20th April, and reaped in September (Malabar Kanny) and is known as the Kanny crop.

The second is usually sown about the 1st of August, and reaped in February (Malabar Kumbhom) and is known as the Kumbhom crop.

The Kanny or first crop is sown broad-cast, and is usually not supplied with artificial water, merely requiring the occasional local showers for the first 30 days after it has germinated. After the 30th day, artificial watering is started, and continued up to the 110th day when it is stopped.

The actual watering should be conducted as follows:—

Between the 30th and 90th days, that is for 60 days, 2 inches of water should be admitted over the field on every eighth day.

Between the 90th and the 110th day, or for 20 days, 2 inches of water should be admitted every sixth day.

These quantities are equivalent to 0·01 c. ft. per second, per acre, for the first period of 60 days, and 0·015 c. ft. per second, per acre, for the 2nd period of 20 days.

The total quantity amounting to 77,760 c. ft. or 2,880 c. yds.

The Kumbhom or second crop is started in seed beds; during the first ten days a small supply of water only is let on to the beds, just sufficient to prevent stagnation. From the 10th to the 35th day, a rather larger supply is necessary. On the 35th day, water is shut off.

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About the 45th day transplantation is effected. After transplantation, and for 90 days (up to the 135th day, assuming transplantation to have been effected on the 45th day) 2 inches of water have to be supplied every eighth day.

From the 135th to the 165th day, or for 30 days, 2 inches depth every 6 days. No further supply is made after the 165th day.

These quantities are equivalent to 0·01 c. ft. per second, per acre, for 90 days; 0·015 c. ft. per second, per acre, for 30 days; the total amounting to 1,16,640 c. ft., or 4,320 c. yds. The time, during which water has therefore to be supplied for the 2 crops, is 200 days, and the total quantity, 1,94,400 c. ft., or 7,200 c. yds. that is to say, 1 c. ft. per sec. of water is capable of irrigating 88 acres.

But the duration of the 2 crops and the total quantity of water required for 1 acre, in calculating capabilities of the Project, have been taken to be 210 days and 15,000 c. yds., respectively.

These figures have been taken as a basis of calculation not because they are believed to be accurate but because they are believed to err very considerably on the safe side and are those laid down by Mr. Horsley who was an officer of considerable experience in irrigation in South Travancore. This officer remarks in his pamphlet on irrigation in South Travancore in this connection "statistics of the actual use of water, here or in other parts of India, accurate enough in themselves, do not always go far enough, and never can be relied on except for the particular locality for which they were collected. Still it has been assumed by competent authority that a daily supply of 0·04 of a cubic foot or in round numbers half an inch of water, should be renewed every day, which gives as the requirements 70 cubic yards per day per acre. If that amount is taken and assuming the duration of two crops usually cultivated in the Southern Division to be 210 days, the requirements are 14,700 or say 15,000 cubic yards per acre per annum."

The inaccuracies in these remarks will be patent to any one conversant with the details of rice cultivation in India.

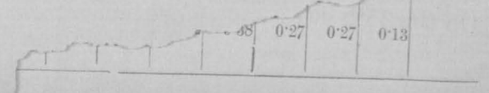
Statistics of the use of water that is of the "duty" of water, in any one part of India cannot of course be blindly applied to any other particular tract, but they are often of the greatest utility, if taken with judgment and common sense in connection with local conditions.

Then again his assertion that the quantity of water assumed by him to be required is supported by "competent authority" is inaccurate and misleading. The quantity assumed is one cubic foot per second for 45 acres. Such a duty would in other parts of India be considered low even for comparatively small tanks with a few hundred acres dependent on them. The old approximate assumption usual in the Madras Irrigation Department where considerable areas were in consideration, was that 2 cubic yards per hour was needed for each acre. This is equivalent to one cubic foot per second for $66\frac{2}{3}$ acres.

Mr. Horsley is also apparently in error in assuming that a full daily flow is required for a period of 210 days in each year.

It is possible that the period on which the crop is actually on the ground, —from the day the 1st seed bed is planted until the day that the last acre is matured may be 210 days—but the whole area does not come into cultivation nor is it matured at exactly the same time; moreover, the first and 2nd crops overlap each other so that although it may for purposes of calculation be right to say that a definite quantity of water is required per acre during the height of the season, the total quantity required for the two crops must not be deduced by using this figure together with the extreme "base" of the full number of days from the date of the first possible planting to the last possible maturing of the crops.

In the same pamphlet he admits that the area under artificial irrigation in the Nanjenaud receives on the average only 9,000 cubic yards per acre per annum (equivalent to about 1 cubic foot per second for 66 acres) from the artificial of supply namely the Pandian channel.



To reconcile this fact with his initial assumption (15,000 cubic yards per annum), he makes a further and unwarranted assumption that the balance of 6,000 cubic yards was obtained from the local drainage streams which fall directly into the irrigation channels.

Now it is well known that the aid afforded by these local streams is a very doubtful matter, and frequently that more harm than good is derived from them, owing to the manner and period at which they are in flood.

Indeed, reading between the lines of his pamphlet it may be surmised that with the existing imperfect system of these channels, and of regulation, about 66 acres are being irrigated by every cubic foot of artificial water, with the aid of course of the local rainfall, which is always assumed as a factor in such cases; or in other words that instead of 15,000 cubic yards of artificial water being required under the existing imperfect system for every acre of two crops per annum, only 9,000 cubic yards are required.

The period during which the flow has to be maintained in the channels, a matter of much importance in a consideration of a reservoir scheme, is given by Mr. Horsley as 210 days. As given above in this note it is 200 days. But even this appears excessive. In the Madras Presidency it is usually taken at about 185 days.

Summing up these various considerations then, rate of evaporation and absorption, local rainfall, local methods of cultivation, it would appear that the prospects of a high rate of duty are very favourable. Although the high rates of 1 cubic foot for 90 or more acres, of the large irrigation systems of the Madras Presidency, may not be realised, yet it would appear that we may at any rate confidently expect the average rate of duty there obtained namely 1 cubic foot per second to 66 acres.

With an assumption such as this, the Pachiparai reservoir, as designed, should be capable of irrigating 60,000 acres of new land. Or to put it in other words, if the anticipations of the quantity of water brought down by the Kothayaur and impounded in the reservoir, are found hereafter to be too sanguine, and only to amount to $\frac{2}{3}$ of that shewn in the calculations, it will still be capable of irrigating the 40,000 acres of new land and supplementing the 25,550 acres of existing land as is at present modestly assumed by the scheme.

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stagnation.
On the 35th day, w...

III. CLAIMS OF THE NANJENAUD AND THE EDANAUD ON THE KOTHAYAUR.

Objects of the Revised Project.

It has been remarked that the objects of the revised Project are, the extension of wet cultivation and the supplementing of the supply to the existing cultivated area. Now there should be no misconception as to the meaning of this.

Object of original scheme.

A perusal of official records will shew that it was almost entirely owing to anxiety to secure a supplemental supply of water to the Nanjenaud, that the enquiry into the diversion of the Kothayaur originated.

The other factor was introduced only afterwards, when it was found, that it would be far more advantageous to impound the Kothayaur water in a reservoir, and that by so doing much more water would become available than was required merely to supplement existing irrigated lands. On working out the Project, it is found, that the benefits to be derived from serving new lands are far greater than the benefits that were originally being sought on behalf of the existing cultivation.

The main object then is to extend the existing area of wet cultivation by 40,000 acres, and the secondary object, to ensure the efficient irrigation of the existing area under the Paralayaur system.

Prescriptive rights of the Nanjenaud.

The following remarks may be made in this connection :—

South of the Nevaur the only sources for artificial irrigation are the Paralayaur and the Kothayaur. Of these, the Paralayaur was appropriated in times gone by, for the Nanjenaud, a district outside the water-shed of that river, and with the exception of a comparatively small quantity, grudgingly given for use in the Edanaud, the Nanjenaud jealously guards its prescriptive right to all the Paralayaur water that it can take.

Natural rights of the Parachalai lands.

Now out of the 40,000 acres of land that it is proposed to bring newly under cultivation by means of the Kothayaur water, about 20,000 acres, may be said to lie directly in the Kothayaur basin. That area therefore, if it has not a prescriptive right to the Kothayaur water, in the strict meaning of the word, at any rate has the strongest natural prior claim. The quantity of water required for developing those tracts to their fullest possible extent should be reserved during the process of so being developed, and not be diverted to other tracts, which would thereby acquire a prescriptive right.

System of Irrigation in Nanjenaud.

By far the largest area of wet cultivation now exists in the Nanjenaud. It has been cultivated from a remote period on the old rough and ready plan of damming the main drainage artery of the country with the inevitable evils of such a method. In recent years, the major channels taking off from this main drain (the Palayaur) have been improved; but, as the Palayaur receives its supply from (1) the Pandiankal, which is dependent on the floods of the Paralayaur, and (2) from the minor rivers * in its own basin, which are dependent on local rain storms, they had to be designed with such hydraulic details as would ensure reception, and conveyance by them, of these flood supplies within the actual short periods of flood, into small reservoirs for storage.

*Thadaviyaur Olakaryaur Poigaiyaur and Vemboomoolay Odai.

In short the whole system of irrigation in the Nanjenaud is merely a modified "inundation" system.

The larger the sectional area of the channels, the larger the sluices, the more frequent the cross dams, the more numerous the petty storage tanks—the more likely are the sudden freshets of local basin storms and floods from the Paralayaur to be retained, and prevented from running to waste.

Modification necessary.

It needs no explanation to shew that to keep up a regular and constant supply in a system such as this from the reservoir, would cause the greatest loss of valuable water and endanger the success of the Project.

Before this Nanjenaud area could be supplied with thorough efficiency from the reservoir, it would be necessary to remodel its entire system and introduce "perennial" irrigation. This, no doubt, could be done with profit to the ryot and Government, and would be following the lines adopted in Egypt where the very ancient, vast and complete system of "basin" irrigation is to be almost entirely abandoned, and the perennial system adopted. The outlay in doing so will be enormous, but the returns anticipated, make the scheme very profitable. And so in a small way here in the Nanjenaud the abandonment of the existing system and the introduction of perennial irrigation without doubt would be very profitable to cultivator and Government. Yet there would be inherent difficulties in effecting it; the chief of these are the interfering with, and in some cases, radical reformation of old established customs and then the finding of the necessary funds, while so heavy expenditure is being incurred on the Kothayaur and other Projects.

Until some improvement is effected, there will be the very greatest waste in supplying the system with water from the Reservoir, and this would be unfavourable and unfair to the uncultivated lands now waiting for the water.

Possibility of improving existing supply without indenting on the Kothayaur

It would probably, for the present, be sufficient to seek some modification of the existing system which will ensure the objects aimed at, namely a good but at the same time not a wasteful extravagant supply to the Nanjenaud fields without very heavy expenditure and without unduly interfering with the immemorial customs and rights of individual cultivators.

I hope shortly to submit a note going in detail into the proposals I would make. It is quite independent of the Kothayaur Project and its execution would take a considerable time. It will, however, be advantageous to undertake concurrently with the Kothayaur scheme the first item of my proposals and that is the more efficient utilisation of the Paralayaur flow. A very large quantity runs to waste to the sea at the very time that it is badly wanted in the Nanjenaud. The proposal that I now submit is to prevent this waste, and divert all or as much as is required, down the Pandiankal to supplement the existing supply.

The following table shews during a series of 5 years the quantity of water taken off for the Nanjenaud and Edanaud and the quantity going to waste over the Puthen Dam.

	1883	1884	1885	1886	1887
To the Nanjenaud ...	141·00	142·84	99·49	164·17	149·85
To the Edanaud ...	22·27	9·63	15·86	21·72	21·70
Lost	326·09	167·09	360·35	177·07	60·53
Total.....	489·36	319·56	475·70	362·96	232·08

Millions of cubic yards

The following table is an analysis of the above, shewing the number of days in each month during which loss by flow over the dam occurred, and the average depth on the crest on those days.

	1883			1884			1885			1886			1887			Remarks.
	Loss.	Days.	Depth.	Loss.	Days.	Depth.	Loss.	Days.	Depth.	Loss.	Days.	Depth.	Loss.	Days.	Depth.	
uary ...	...	...	...	...	...	...	0·99	3	3″	...	...	...	...	...	...	This table is one prepared by Mr. Horsley. Subsequent registers do not bear it out in regard to the quantities running waste in January and May—but even if the small freshets of June and December could be stored the advantages would be great and the cost small.
February ...	4·14	7	3″	...	...	...	...	...	...	...	...	...	...	...	...	
March ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
April ...	...	...	...	...	...	...	...	...	...	...	...	...	0·09	1	1″	
May ...	31·02	19	6″	...	...	...	3·65	11	3″	7·05	6	6″	0·05	1	1″	
June ...	65·42	24	10″	...	...	...	146·08	26	1·6″	102·09	23	1·1″	5·78	3	9″	
July ...	115·83	31	1·1″	4·13	...	...	85·30	29	1·0″	11·08	18	4″	22·68	8	10″	
August ...	68·14	18	1·0″	47·17	...	...	34·20	..	...	10·62	15	4″	...	...	...	
September ...	13·22	14	5″	1·98	4	3″	...	...	...	2·60	7	3″	...	...	...	
October ...	9·79	8	7″	34·23	20	7″	53·29	28	8″	8·84	5	8″	18·70	12	7″	
November ...	17·49	23	4″	43·20	29	7″	36·84	26	7″	33·30	30	6″	4·45	10	3″	
December ...	1·04	1	6″	36·38	27	7″	0·00	3	8″	1·49	5	3″	8·78	9	5″	
Million C. yds...	326·09	...	...	167·09	...	...	360·35	...	...	177·07	...	...	60·53	...	...	

It will be seen at a glance from the first of these tables that the quantity of water going to waste is far more than is taken off for the Nanjenaud and Edanaud; indeed that there is really an ample supply of water—if only it could be made use of.

Now what is the quantity that the Nanjenaud lands require in addition to their existing supply?

I have repeatedly asked this question and have carefully searched in official records but have not succeeded in getting even an approximate figure and it is well-nigh impossible to estimate it with the existing system. It is however generally admitted that, but for exceptional years, the want of water is felt, really badly, only in part of the months of May and June, and in parts of December and January:—that is to say, at the beginning of the Kanny crops, to keep alive the young plants started by local rainfall, and at the end of the Kumbhom crop, to mature the plants and keep them from being withered by the strong sun. The actual quantities required for this are but small and not the same as is necessary to be supplied in the middle of the irrigation season.

The usual number of days during which this scarcity is felt, is about 20. That is about 10% of the whole period, 210 days, taken to rear the two crops. If then 10% of the total quantity required for two crops is allowed as necessary for aiding the existing supply, there will be an ample margin. Now if the second table be inspected it will be observed that during the months of May, June and December considerable quantities of water varying from 3 to 10 inches in depth are being annually lost at the Puthen dam.

When it is borne in mind that 6″ flowing over the dam represents a flow of 326 cubic feet per second and 8″, 47 cubic feet per second, it may readily be understood that if these small freshets are conserved and diverted into the Nanjenaud they will prove of material aid—and thus save much of the drain on the reservoir. This may be effected by fitting an arrangement of automatic falling shutters on the crest of the Pachiparai reservoir, or to a portion to it by fitting an arrangement of automatic falling to the Pachiparai reservoir, or to a portion of this Pandian dam, similar to those proposed for the escape at a suitable point, to keep the channel deeper than and inserting a scouring sluice in the body of the dam, the entrance to the channel clear of silt.

It was long ago proposed to raise the crest of the anicut to effect this object; but this could only have resulted in the silting up of the river bed to the new crest level and the loss of the water would be the same as previously. By the use of the automatic shutters, which will fall as soon as the flood reaches a calculated height on the masonry crest, the sand will be carried forward over the crest and thus silting prevented.

This work will not be costly and may possibly be found to go far towards meeting the wants of the Nanjenaud. In the event of its failing to do so, the Pachiparai reservoir may be indented on.

Nanjenaud wants to be subordinated.

I would very strongly urge the policy of subordinating the interests of the existing cultivation, to that of proposed cultivation. To admit water in unlimited quantities to the Nanjenaud lands in the early days of the project, merely on the ground that water was available in the reservoir, and prospective irrigation had not developed to such extent as to utilise it, would be a most fatal step. Such a step would as already shewn, result in enormous waste of water in the existing imperfect Nanjenaud system; it would demoralise the Nanjenaud ryot by confirming him in his wasteful methods, and make the hoped for improvement of the system an impossibility; it would give him a prescriptive right to the use of an unreasonable amount of water and would thus prevent the development of new cultivation up to the ultimate area anticipated by the project. This is a matter that seriously affects the financial success of the project and the benefits that will be realised from it in opening new country and developing industry.

If the scheme, that I have alluded to here, is found not to meet the Nanjenaud wants and water is available in the Pachiparai reservoir, there would be no objection to affording a supply that may be decided to be sufficient, but no more. This would be effected by establishing a regulator in the Pandian channel, just below the proposed off-take of the new Tovala channel.

Accurate working of the regulator would be enforced on strict rules, laying down the exact depths of water to be maintained at the various masonry works &c. and before introduction of such an arrangement, the agreement of the Nanjenaud ryots should be individually obtained.

IV. ENGINEERING DETAILS.

i. The Reservoir.

Area and capacity.

The reservoir will have an approximate area of 7 square miles, and a capacity of 5,221 millions of cubic feet. It is shewn in drawing No. 2. Contours have been run at R. L + 254·00, + 279·00, and + 289·00. The contour at R. L +299·00, the full supply level, is now in progress, and will very shortly be completed. It has been shewn on the drawing by approximation from the contours already taken.

Present condition of the surface.

The whole area is covered with secondary forest and thick undergrowth. The clearance of this jungle, prior to the submergence of the area, has been under serious consideration, in order to avoid the pollution of the water by the decay of trees and vegetation. A small area of about 300 acres was actually cleared experimentally, but the cost was so high, and the value of the timber obtained so small, that it would almost appear out of the question to proceed further. The matter is however still under consideration, and if it is possible, without adding very greatly to the capital cost of the project, to effect a thorough clearance, it will be most desirable; but no provision is made in the revised estimate now submitted. The pollution of the water in the Peryaur lake, is said to have caused an increased incidence of fever in its immediate locality. During the first year also, that water was supplied to the Melur taluk of the Madura District, there is reported to have been a marked increase in malarial fever, and it should be borne in mind, that on its way there, through many miles of sandy river bed, it would probably have become to some extent purified; while there would be but small chance of this, in the few miles of channel from Pachiparai to populous districts.

ii. The Dam.

Site of dam.

The site selected for the dam by the late Chief Engineer was about 410 feet below the site on which it will now be erected.

Work was actually started on the original site in 1895 and some Rs. 30,000 spent on it, when it was found to be quite unsuited for the purpose, and was accordingly abandoned.

The site now adopted was first thoroughly tested by means of trial pits, which clearly indicated a rocky base within reasonable depth from end to end. These are shewn on the longitudinal section.

Materials of construction.

Concrete has been adopted for the construction of the dam in preference to other form of masonry.

There is a considerable amount of unskilled labour available from parts of the country not very far distant from the site. Whereas, skilled labour for masonry work is very scarce and costly throughout Travancore.

The actual cost of concrete would not be less than ordinary rubble work in mortar, but owing to the above consideration the former is adopted as being less likely to cause risks of failure from inferior work or risks of slow progress owing to strikes or to deficiency of skilled labourers.

Stone.

The stone available at the site is a sienite of excellent quality.

The following table exhibits the crushing stresses obtained at experiment made at the College of Engineering, Madras.

No. of specimen.	Cross sections of cubes. Length in inches.	Breadth in inches.	Depth in inches.	Area in Sq. inches.	Crushing load in tons.	Crushing load in tons per Sq. inch.	Crushing load in tons per Sq. ft.	Remarks.
1	4·085	4·076	4·081					
2	4·090	4·056	4·045	The specimens resisted crushing under a pressure of 100 tons.				
3	4·064	4·065	4·085					Sp: gravity. 2·675 to 2·679.
4	4·079	4·063	4·090					
		Specimens then reduced in size and crushed with following results.						
1	3·090	3·039	3·131	9·369	72·185	7·705	1109	
2	3·081	3·034	3·078	9·348	58·60	6·269	903	
3	2·077	2·096	2·090	4·352	45·50	10·45	1505	
4	3·078	3·055	3·077	9·404	92·82	9·871	1421	

The results do not shew very great uniformity; the cause being that the specimens tested, were selected haphazard from some old heaps of stone. The stone, especially that near the surface, is occasionally traversed by veins which no doubt render it liable to failure along the line of the veins and this is probably the cause of the variation in the tests. Surface stone containing veins will therefore be rejected in the work.

Mortar.

The mortar that will be used, will be formed from nodular limestone mixed with a certain proportion of surkee or burnt and sifted clay, and sand.

The original estimate contemplated the use of mortar made with this limestone without any admixture of surkee.

The following experiment however made it clear that this limestone is but slightly hydraulic and therefore by itself unsuitable for work.

Rough experiments in mortar of fresh limestone.

No.	Proportion. Lime.	Sand.	Surkee.	Specimen 1 immersed immediately after mixing. Examined after 24 to 72 hours.	Specimen 2 immersed after 2 hours. Examined after 24 to 72 hours.	Specimen 3 immersed after 4 hours. Examined after 24 to 72 hours.
A	1	2	0	Not set, crumbled	Very slightly set crumbled ...	Not much improved.
B	1	2	½	Slightly better than A but still crumbled	... ...	
C	1	1½	½	Better than B, but not setting well	Setting a little.	
D	1	2	1	Better than C, but not set ..	Setting fairly	Setting better than Spec: 2.
E	1	1	1	Continued to set	Setting better than 1	Setting better than Spec: 2.

These rough experiments were conducted locally, and by the experience gained, cubes of surkee mortar containing the ingredients in the proportions which appeared to be suitable, were prepared and submitted to the Civil Engineering College Madras, for testing in the testing machine at that institution with the following result.

Results of tests of mortar blocks carried out at the Civil Engineering College at Madras on 29-1-97.

No. of specimen.	Proportions of Lime.	Sand.	Surkee.	Dimensions in inches.	Area in sqr. inches.	Total load in tons at which first crack appeared A.	Total load in tons per sq. ft.	Crushing load in tons.	Crushing load in tons per sq. ft.	Remarks.
1	1	1½	½	6″×6″×6″	36	4·49	17·96	5·76	23·04	These blocks were made and immersed in water and kept for about 8 months before the tests were made.
2	1	1	1	6″×6″×6″	36	6·41	25·64	10·14	40·56	
3	1	1	1	6″×6″×6″	36	14·98	59·92	14·98	59·92	

These results obtained so short a time after mixing shew a mortar amply strong and quick setting.

Blocks of concrete made up with mortar of the proportions mentioned above were at the same time made and tested and gave the following results.

Results of tests of concrete blocks.

Number of specimen.	Proportions of Stone.	Lime.	Sand.	Surkee.	Dimensions in inches.	Area in square inches.	Total load in tons at which first crack appeared.	Total load in tons per square foot.	Crushing load in tons.	Crushing load in tons per square foot.	Remarks.
1	3	⅔	1	⅓	9″×9″×9″	81	17·04	30·29	26·30	46·76	These blocks made and immersed in water and kept about 8 months before the tests were made.
2	3	½	1	½	9″×9″×9″	81	24·52	43·59	29·51	52·46	
3	3	1	1	1	9″×9″×9″	81	29·05	51·64	30·86	54·87	

As might have been expected, the crushing stresses approxim to those obtained for the mortar bricquettes.

Limiting intensity of stress.

These results sufficiently justify the adoption of 8 tons pressure per square foot as a perfectly safe limiting pressure which the concrete will bear.

The profile of dam.

The deepest point in the bed of the river where sound rock foundation will probably be found is R. L. +192·0, but in designing, this has been taken as +182·00. The maximum level above which the flood water is designed not to rise is R. L. +301·25 and +302·00 is taken as the crest of the dam giving a dam of 120 feet in height for the purposes of calculation only.

In the estimate the quantities are taken out, assuming a R. L. of + 192·0 at the lowest point and R. L. +302·00 at the crest of the dam.

The profile has been designed by Molesworth's method drawing No. 9. By its means a profile can be designed which complies very approximately with the practical conditions that are considered essential for the safety of high masonry dams.

These conditions briefly are as follows :—

(*a*) There should be no appreciable tension at any point in the masonry, whether at the outer face, when the reservoir is full, or the inner face, when it is empty ; or in other words the lines of pressure in both such cases should fall within the middle third of the width of the profile.

(*b*) That the intensity of pressures at the faces, shall not exceed a certain limit, decided upon as the safe crushing load for the materials used, in this case 8 tons per square foot.

(*c*) There should be no danger of sliding at any horizontal layer of the masonry.

A strict observance of these conditions will produce a type of profile having a factor of stability of 2.

A profile has also been designed by theoretic mathematical process which is shewn in drawing No. 10.

In drawing No. 11. this theoretic and Molesworth's profile are superimposed and the difference between them exhibited graphically.

The exact differences at different sections may also be obtained from the tables given on drawings No. 9 and No. 10. It will be noticed that from 40 feet down to 90 ft. from the top of the dam Molesworth's profile differs somewhat from the theoretic profile. At the point of greatest divergence, the factor of stability is 1·80 as against 2 in the theoretic profile. This divergence is not very considerable ; indeed it is really less, because the vertical components of water pressure on the batter of the front face, has been neglected in the calculations.

It will also be noticed that there is a considerable excess of material in the lower portion of Molesworth's profile, as compared with the theoretic profile. This excess is, however, rather a point in favour of Molesworth's profile ; because it has been a moot point, whether the practical assumptions of the directions of pressure, in the portions of the structure near to the faces, on which the theoretic calculations for theoretic profiles are based, are really correct. It is asserted by many, that the intensities of pressure near to the front and back slopes, will be greater than those given by these theoretic calculations, because the directions of the resultant pressures near the surfaces, will be tangential to the curve of the batter, whereas in the calculations, the pressures taken account of, are only the components normal to the horizontal plane. Hence the pressures at the outer toe, when the reservoir is full, will be greater than those shown in the theoretic profile, and this would indicate a greater width somewhat similar to that given by Molesworth's formula. Molesworth's profile is therefore adopted.

Rubble facing.

The dam will be built of concrete to this profile. The rear or down stream face will be protected by a thickness of 3 feet of rubble masonry : but the front face will merely be plastered with surkee mortar cement to render it watertight.

The 3 feet of rubble masonry is not essential to its stability against the stresses shewn in the profile calculations, and has not been taken into account in calculating. It will, no doubt, add to the stability, but its object is to retain the concrete in position during construction and at such times during construction as it may happen to be subjected to the violent action of flood water running over the top of the work and down its rear slopes.

Culverts through the dam.

The dam will be pierced by two under sluice culverts with sills at R. L. + 207·00 for the unwatering of the reservoir (as described further on), by another culvert at R. L. + 229·00 for the turbines and by the head sluices to the left bank channel at R. L. + 254·00. At the extreme right flank for a distance of 450 ft. the crest is lowered to R. L. + 296·00 and automatic falling shutters fixed on it. This portion will be utilised as a portion of the escape for surplus flood water. The clear overfall at the highest point will be on to rock and will not be more than 30 feet. This is not excessive and as the rear slope of the dam is for this height practically vertical, and protected with rubble masonry, there is no need to fear the action of the overflow. In order to prevent the flood water from flowing along the face of the dam towards the river vide drawing No. 4 a masonry training wall is provided to divert it to a safe distance.

A road way 13 feet in width is provided from end to end of the dam.

permission to send the plans and estimates to the Chief Engineer

for

iii. Under Sluices.

Objects.

It is now the almost invariable practice to provide under-sluices at the base of dams. These were absent in the original project.

They are considered essential for the following reasons.

1. To prevent the silting up of the reservoir bed and so lengthen its life.
2. To permit the unwatering of the reservoir if on account of accident or from a desire to examine the dam or to carry out any repair it is desired to do so.
3. To facilitate construction.

Prevention of silting.

The first consideration is one of the very greatest importance and has of late been a point of much controversy.

The many large tanks in the Madras Presidency which have become practically inoperative from this cause is a sufficient object lesson to justify a few remarks here.

It has been asserted, for instance that the Bhatgarh reservoir in the Bombay Presidency, one, of about the same area and capacity as that contemplated at Pachiparai, would be silted up to the level of the crest of its dam within 80 years, were not the scouring action of under-sluices resorted to. If this be true, then by the time the work had attained its full value in serving the land, it will itself just be about to gradually diminish in ability to retain the full quantity of water for which it had created the demand, and in 80 years from its completion would cease to exist as a reservoir.

Of course the rapidity with which silting would occur, would depend on the quantity and quality of silt borne in the water. We have no exact information on this point for the Kothayaur. Fortunately from some rough tests lately made this silt appears singularly small but the records of other rivers shew that at times it may be considerable. For instance the Rhone and Vistula bear a proportion of silt to water as high as $\frac{1}{75}$ and $\frac{1}{15}$. The Nile $\frac{1}{666}$, the Indus $\frac{1}{2357}$, and the Yelvandi river which supplies the Bhatgarh reservoir $\frac{1}{1000}$.

The beneficial effect that is ascribed to under-sluices is, in my opinion, overrated. For, unless the flood water is discharged through the sluices with very little head, that is to say, unless it is confined more or less to the natural river bed and prevented from spreading out over the reservoir there must be a considerable check of velocity where the supplying streams enter the reservoir, with an inevitable result, namely, the deposition of such silt particles as the reduced velocity is unable to carry forward (chiefly sand).

Those who advocate the sluices for the lengthening of the life of the reservoir assert that, it is the early monsoon floods that bring down the largest quantity of silt, and that during those floods, the sluices should be kept open to discharge all the water with such small afflux that there should be no appreciable check in velocity, and that the silt particles would therefore be carried out of the reservoir area through the sluices. This is no doubt true as far as it goes, but the fact is overlooked that the silt that is brought down throughout the rest of the * monsoon, which must aggregate a greatly larger quantity than that borne by the few early floods, could not be influenced by the under-sluices (which would admittedly and necessarily have to be closed during the season) and would be deposited on the reservoir bed.

*Indeed from specimens of flood water collected during different floods in the Kothayaur the largest quantity of silt occurred not in the early floods but in flood as late as the beginning of September.

The effect of under-sluices in the dams across the Godavery, Kistna, and Kavery rivers (and the same is noticeable elsewhere in India) is merely to scour out a deep channel for a few hundred feet immediately above and in front of them, the rest of the river bed being choked with sand to a level with the crest of the dam. They have failed to maintain a deep bed in the river except in their immediate neighbourhood.

The deposit consists almost entirely of sand the lighter silt particles being carried forward. In my opinion, therefore, but little beneficial effect would result by the introduction of under-sluices, in arresting *sand* deposits, although the lighter silt would no doubt be carried out.

On the other hand, it should be stated that in the designs for the Bhavani dam in the Madras Presidency, a work likely soon to be undertaken, under-sluices are to be provided with the intention and expectation of preventing silting. Similarly under-sluices were built in the Bhatgarh dam; and in the case of the Assuan dam, proposed to be built across the Nile, no less than 140 under-sluices aggregating 3,070 square feet in area and capable of discharging the whole of the Nile flood water with an afflux of about 14 feet have been introduced in the dam, at very great cost, with this express object.

And I should at once, in the light of the opinions expressed in these designs, recommend that under-sluices of sufficient power be provided, were it not for one practical difficulty. It is this. The demand for water from the reservoir will, as explained earlier in this report, begin at the middle of May and continue throughout June and July. Now the early monsoon floods occur towards the end of June and in July: under this system of preventing silting these floods would have to be entirely discharged through the under-sluice immediately they occur. It would, therefore, be necessary at that time to keep the reservoir practically empty, and this would be inconsistent with the imperative necessity that would exist at that very time, for a comparatively full reservoir for supplying water for irrigation purposes. Unless therefore the system of irrigation in the south of Travancore could be revolutionised to suit the arrangements of the reservoir, the under-sluices could not be put to use as silt clearers. The difficulties in the way of this would be well-nigh insuperable.

In these circumstances the first consideration in favour of going to the expense of under-sluices need not have much weight.

Utility in the present undertaking.

The two remaining arguments in favour of under-sluices, namely, to permit unwatering in case of necessity, and to facilitate construction, are however quite weighty enough to warrant the introduction of sluices for those purposes.

During the construction of the Peryaur dam the greatest hindrance to the work was caused by omission to form under-sluices at the base of the dam to pass the ordinary river flow and so keep the work free from submergence. And now the Chief Engineer, Madras P. W. D., informs me that the omission was a lamentable mistake and is now after construction very seriously felt as it is found very desirable to unwater the reservoir for inspection &c., but it is impossible to do so.

Two under-sluices have therefore been provided. They will be closed by cast iron gates of special design 8 feet high and 4 feet wide.

Description of under-sluices.

The sills will be placed at R. L + 207·00. When the reservoir is full the gates will have a depth of 84 feet of water above them. It will never however be necessary to make use of them under such a condition. If made use of for unwatering the reservoir, the gates would not be raised until water had fallen in the reservoir to about R. L + 260 00 i. e. under a pressure due to a head of 53 feet of water over the sill, which amounts to 98,000 lbs. on each gate. But in addition to this, the friction of the mechanism and the possibility of mud, trees, stones collecting against the face of the shutters, renders the ordinary form of gearing for operating sluice gates totally unsuitable for these.

In the Bhavani and Assuan dams, the under-sluices of which, will have to be worked under about the same head of water, Stoney's patent roller gates are provided. These are said to be quite efficient: but the cost is very heavy. One gate alone delivered in England exclusive of carriage and fitting costs £ 900 or about Rs. 15,000. Including the cost of fixing two such gates would probably involve an expenditure not much less than Rs. 50,000.

To meet the difficulty I have designed an arrangement which I trust will work efficiently and is much cheaper. This is shewn in detail in drawing No. 13.

A well will be built in front of the dam. In its front face an iron gate is shewn capable of being operated by means of a steel shaft and gearing. At the back of the well, at the entrance to the sluice culvert under the dam, there will be a second gate built in three sections, each being capable of movement independent of the other. The actuating mechanism will be of a special type to enable this to be done.

The front shutter being closed, access to the rear shutter will always be possible by means of the well. The rear shutter will, therefore, always be accessible for being kept in thorough repair and lubrication, and free and easy working order.

When it is desired to pass water through the sluices, the ~~real~~ rear shutters after thorough examination, scraping, fitting and cleaning will be closed; the well will then be filled with water by means of the small inlet pipe, shewn in the drawing, and the water pressure on the front of the front-gate, being thus balanced by the water let into the well in rear of it, there will, it is expected, be no difficulty in lifting it by its gearing, only the friction of its mechanism having thus to be overcome. On this being done, the entrance to the culvert under the dam will be effected by raising each successive section of the rear gate, which being thoroughly cleaned and lubricated and the pressures on the sections comparatively small, will be a matter of not great difficulty.

The sill in front of the well is extended up-stream sufficiently to permit an iron grill being fixed to prevent logs, boulders or other such debris settling in front of the front gate and being drawn into the culvert when the gates are opened. The floor of the culvert will be lined ashlar, each stone being of sufficient length to extend across the culvert and under each abutment. The sides and arches of the culverts will also be of ashlar work.

The discharge through these under-sluices will, of course, vary with the head of water; but it is calculated that they could unwater the reservoir between R. L. + 254·00 and R. L. + 207·00 in 6 days. This should be rapid enough to permit an examination of the dam and the execution of any repairs found necessary.

iv Head Sluices.

Position.

Considering the head-sluices to the left bank channel first, the sills of these sluices will be at R. L. + 254·00. There will thus be when the reservoir is full (R. L. + 299·00), a depth of 45 feet of water over their sills.

Difficulties in design.

Here again we have been confronted with the same difficulty in the means of regulating the flow through them, as in the case of the under-sluices. The problem, however, is here a different and more difficult one. In the case of the under-sluices, it is only on very few occasions in a year that the gates need to be moved, and the operation may be carried out slowly and with deliberation; whereas in the case of the head-sluices the necessity of regulating the quantity of water that passes through, to suit the rapidly varying requirements in the irrigation channels, makes it imperative that the gates be at all times under complete and speedy control.

How overcome.

As before, so here, this could be effected by the use of Stoney's patent roller gates, but as they would probably cost not less than 1½ lacs of Rupees, a very large sum compared to the total cost of the project, I have, after much careful consideration, designed a structure, which I hope will save so large an expenditure and meet every requirement.

To overcome the difficulty of the great head of water, the design provides for three sets of gates, opening into a chamber in front of the dam proper, each set being capable of discharging into the chamber the full quantity of water required for irrigation purposes.

Each set of gates will be at a different level. The upper set at R. L. + 284·00 the intermediate at R. L. + 271·00 and the lowest at R. L. + 254·00.

It will thus be seen that water can be admitted to the chamber and thence to the channel at any state of the reservoir without having to overcome a pressure on the gates due to a greater depth than 17 feet. Moreover, that the excessive velocities through the sluices that would be set up if the ordinary type of vertical gate were used will be avoided as it will be destroyed by its fall in a vertical direction into the chamber.

The chamber will communicate directly with a series of culverts under the main dam. These culverts are of 4 feet span and the piers between them will be 5 feet thick. Culverts of larger span than these will be inadvisable as the pressures that would result on the abutment and intermediate piers would become very excessive.

Turbines for operating the sluices.

The series of gates will be operated by means of turbines and gearing of a simple description and will thus be under prompt and easy control of one individual. This is a matter of great importance as regulation of sluice gates by manual power has always proved very uncertain and unsatisfactory. The turbines will be of ample power to operate any series of shutters with a head of 20 feet. They will be set up in a well communicating with a culvert passing through the dam.

The sill of this culvert will be at R. L. + 229·00 so that with a water level in the reservoir as low as head sluice sill level (+ 254·00), there will be a head of about 20 feet of water to drive the turbines.

The head-sluices to the right bank channel will be quite different. The high rocky spur at the left flank of the dam precludes the selection of any other position for the head-sluices and offtake of the left bank channel. But the country at the right extremity, is more favourable. There are several points on the lake contour where head-sluices and an offtake for the right bank channel can be conveniently fixed. A point has been selected at a saddle which has a reduced level of about + 289·00.

As a simpler and more economical arrangement three independent sluices will be built with sills at R. L. + 282·00, + 268·00 and + 254·00 and thus the head of water against each gate reduced to workable limits.

The differences in level between the sills of the sluices and the bed of the right bank channel will be removed by means of masonry drops constructed in the channels in the rear of each of the sluices before they combine in the right bank channel proper.

The sill of the lowest vent is placed at R. L. + 254·00 although the bed level of the right bank channel is at R. L. + 240·00 only. If any advantage is expected by drawing water at the 240·00 level a separate sluice would have to be built.

v. Escapes.

Position and length.

The revised estimate provides for two escapes, one 450 feet long at the right extremity of the dam, and one 550 feet long at an adjoining saddle, as shewn in drawing No. 4.

In order to arrive at a thoroughly satisfactory arrangement for the escape of surplus flood water, very careful preliminary investigation has been made. It has enabled us to select a design of escape, such that, the surplus water may be got rid of with absolute safety, at a very moderate cost.

How surplus discharged in the original scheme.

In the original estimate for this project, it was designed that the surplus water should escape with a considerable depth (about 10 feet), in order to shorten the length of the escape, for the sake (mistakenly) of economy. With such an arrangement, in order to prevent the flood water from overtopping the main dam, its crest had to be raised above the level to which the floods would rise on this escape; but on their subsidence the actual quantity of water retained in the reservoir would lie below the level of the crest of the escape itself. It is obvious,

ermission to send the plans and estimates to the Chief Engineer

or Irrigation at Madras.

therefore, that some 10 feet height of the masonry in the main dam would be useless for purposes of pounding water in the reservoir. When it is borne in mind that the quantity and cost of this useless mass of masonry would amount to about 5,70,000 c. ft. and 1,08,300 Rs., respectively, the imperfection of such a design will be realised.

How arranged for now.

The design now submitted will be made clear by the drawing No. 22. None of the masonry in the dam will be useless in the respect explained above. The crest of the weirs or escapes is placed at R. L. + 296·00, or 3 feet below the full reservoir level. On this masonry crest, are erected automatic falling gates. These are so designed that while standing erect on the masonry weir their upper edge will be exactly at full reservoir level. They are attached to the masonry by means of bars. One end of each of which is pivoted to a particular spot on the gate and the other to the masonry.

As long as the pressure of the water on the portion of the gate below the point of pivoting, is in excess of the pressure on the portion above that point, the water in the reservoir will of itself maintain the gate in an erect position on the weir. But as soon as the reverse is the case, the gate will fall flat on the masonry of the weir, as shewn in the drawings, and the water in the reservoir be free if so permitted to escape to the level of the masonry crest.

The exact point at which the pivoting of the bars to the gate is effected in the design, is calculated (vide appendix I) to ensure that the gates will fall as soon as the water has risen to a height of $1\frac{1}{2}$ feet above their upper edge that is to about R. L. + 300·5. There will then be $4\frac{1}{2}$ feet of water flowing over the crest. With this depth 31,000 c. ft. per second will be discharged; but as is explained further on, it is possible that so large a quantity as 39,000 c. ft. per second, may have to be disposed of. With such a quantity passing over the weir it is calculated that the depth on its crest will be $5\frac{1}{4}$ feet and all masonry works are designed to meet such a contingency.

It will thus be noted, that the relief and safety of the reservoir from the effect of receiving larger quantities of water than it can safely retain, is effectually provided for by an automatic arrangement; and that is of course a very desirable point. Any arrangement dependent for its timely working on a staff of watchers, would in practice be found very risky, and likely to endanger the whole work. It will however be necessary as soon as the flood begins to abate for the staff of lascars to proceed to raise the shutters again into an erect position on the weir crest and so retain the water at full supply level not allowing it to run to waste down to the level of weir crest.

By actual experiment it has been found, that 3 or 4 men can easily effect this by the rough and ready arrangement of standing on the weir crest and raising each shutter. But here, a foot bridge has been provided clear of flood water, on which is placed a wynch running on rails, by means of which the raising of the shutters can be very easily and rapidly effected.

Quantity to be surplussed.

The quantity of surplus flood water that the escapes are capable of discharging is, as stated above, 39,000 c. ft. per second.

It should be explained how these figures are arrived at as they appear very high for a catchment area so limited as that of the Kothayaur.

How arrived at.

During the past few years, a daily register of the depths of water in the Kothayaur river has been maintained at Pachiparai. By means of this, it has been estimated, that the maximum discharge in the river during that period, has been 39,000 c. ft. per second. But the calculations have no pretension to great accuracy; and at best indicate the maximum discharge during those few years only. Some check has therefore been endeavoured by means of the ascertained rainfalls.

Rainfall registers.

Registers of rainfall at Augusteermalai, Eridge, Corrimoney, places on the elevated hilly tracts of the Kothayaur basin, and close neighbourhood, are available for a good many years, so that a fair idea of maxima falls of rain over those

tracts may be formed. Registers of the tracts at the foot of the hills have also been kept during the past 2 years at Pachiparai, Colasagaram, and Ponmanai.

Catchment area.

By means of these, the maximum possible run off in a given time from the Kothayaur catchment might be estimated with fair approximation, and afford a check on the river gauging, were it not, that owing to the inaccessible nature of the country above the plains, no topographical survey of it has been made, and we are unaware of the area of the catchment basin above the site of the dam (Vide drawing No. 1).

Mr. Horsley states that the area above Pachiparai, the site of the dam, is 91 square miles. Mr. Bourdillon who has personal acquaintance with the country estimates its area about 100 square miles.

The Government of India trigonometrical survey map of this portion of the country is practically a blank in the hilly portion, where the Kothayaur is now known to take its rise; the source and course of the river is not correctly shewn on it. It is now known that the Kothayaur takes its rise in the hills behind Muthukuzhi peak and flows about due north for some 8 miles to near Motachy peak along a deep valley, falling rapidly from about 3,500 to 1,400 ft. in elevation at that point. It there suddenly trends to the south-westward and falls by cascades in a few miles to the level of the proposed reservoir only some 300 ft. above sea level.

By an inspection of this map, it would appear a matter of considerable doubt whether the catchment area can possibly exceed 80 square miles and for purposes of calculation it is here assumed to be of that area.

Mean annual rainfall.

The following table shews the mean annual rainfall at the various stations the details of which may be found in Appendix.

Number.	Station.	Mean fall in inches.
1	Augusteermalai	199
2	Eridge	201
3	Corrimoney	146
	Mean.....	182

A mean of these three stations, namely 182 inches per annum, may be taken as the rainfall over the whole 80 square miles of basin. This would give 1,254 millions of c. yds. as actually falling during an average year.

Now from the registers of Kothayaur discharges at Pachiparai, referred to above, it is calculated that the average annual quantity of water that passes down the river is 1,070 millions of c. yds.

Ratio of flow-off to rainfall.

It will thus be seen that the mean ratio of flow-off to rainfall for one year is as 1 to 1·17.

The maximum flow-off (which is the important point) during any short period will however stand in a higher ratio to the actual fall. These will occur when a heavy fall of rain takes place after continuous, but possibly light, falls, sufficient to saturate the soil to such an extent as to prevent its absorption of any further quantity. The period is generally between July and December.

Appendix I gives details, which shew that the maximum run-off will probably occur in the month of October, and will bear a ratio to the fall of 1 to 1·04 or nearly as 25 to 26.

In the year 1896 the highest recorded flood up to that time took place. The velocity was ascertained by means of a current meter. The discharge was ascertained to be 35,000 c. ft. per second.

In 1897 a heavier flood than this occurred; the gauge reading giving a depth of 1′–6″ greater than the 1896 flood, but unfortunately as the current meter was out of order, only an approximation at the velocity was possible, and the discharge worked out at 39,000 c. ft. per second. Although this quantity may be excessive it is safer to adopt it as a possible maximum.

Coefficient of discharge.

If these figures are substituted in Ryves formula for discharge $D=C\sqrt[3]{M^2}$ it will be found that C must have a value of about 2,100. At first sight this appears somewhat startling. But after a consideration of the actual circumstances of this locality this high value will not appear extraordinary. If this ascertained discharge of 39,000 c. ft. per second, is multiplied by the factor 1·04, the actual quantity of rain falling per second over the whole 80 square miles is obtained—it will be 40,560 c. ft. per second. Reducing this to depths in inches per hour, we obtain the result that a flood of this intensity could have been caused by a fall of 0·78″ per hour over the whole area of 80 square miles or of 1·56.″ per hour over half the area of 40 square miles or of 3·12″ per hour over one quarter the area of the catchment or over 20 square miles.

A duration of such rainfall for 24 hours would represent a depth of 18·7 inches of which 18 inches would run off and 0·7 inches be absorbed.

Now the catchment area being comparatively small, a heavy rainfall over the whole of it, is not very improbable, and still less improbale over one-half, or one-quarter of it. Moreover, the rates at which it must fall in each case to produce the maximum flood, is by no means impossible especially during cyclonic rains of the north-east monsoon. When these considerations are borne in mind, as also the fact, that country outside the reservoir bed is very precipitous, that its soil is permanently saturated, that its valleys are narrow and run in the direction of the monsoon currents, and that the floods are generally of short duration, rising to a maximum in 3 to 4 hours and subsiding as quickly, the improbability of so high a coefficient as 2,100 is much lessened.

As a further check on its probability, it may be noted, that the ascertained coefficient for the Tambrapurni river in the Tinnevelly district which takes its rise in the hill tracts near to Augusteermalai is 861. This coefficient is much higher than is usual for such rivers on the east coast, and is attributed to the fact that a part of its catchment is in the Travancore hills about Augusteermalai peak. The coefficient is calculated on the whole catchment, of which, the hilly tracts is but a small portion; the coefficient for the low country tract could not be more than 300, so that the hilly tract must have one very much greater than 861, and thus would approximate to the very high value that is now found for the coefficient on the western slopes draining into the Kothayaur.

At any rate, these considerations point to the necessity of providing very ample escapes, as has been done, to ensure the safety of the reservoir and dam.

vi. Construction.

Diversion of river necessary.

Drawing No. 3 is a survey, shewing the general arrangement at Pachiparai and its neighbourhood, in connection with construction of the dam and other head works.

The level of the undisturbed bed of the river at the site selected for the dam is +207·00. This consists of sand overlying the rock at considerable depth. It is a matter of the first importance, that the masonry which is laid immediately over the rocky foundation should be of unquestionable quality. It is therefore necessary to keep the excavated hollow below the bed of the river, free from w[illegible] during constructive operations. This involves a diversion of the river. [illegible] this, a masonry dam 35 feet high is to be erected, about 1,050 feet ab[illegible] the dam site (vide drawings No. 5 & 6). This will raise the water to a [illegible]e available divert it into the yella on the right bank of the river. [illegible] rain over those

foundations and round the rocky spur behind it, by means of a timber flume, whence it will be discharged into the river below the dam site.

Discharge through diversion cut.

It is calculated that about 500 c. ft. per second can be diverted in this way and as for some 6 months in the year the discharges in the river but seldom exceed that figure, unimpeded operations on the dam foundation for that period will be probably secured.

Disposal of water at various levels.

The greatest care may therefore be taken in securing a sound base for the masonry. The work will proceed in this manner until about R. L. + 220·00 is reached. At this level the two under-sluices will have been completed and their discharging capacity about 960 c. ft. per second, at that level, may be added to that of the diversion channel in disposing of river flood water, without the masonry being overtopped and work interrupted; so that as the work progresses above the 220·00 level, the chance of interference by floods will be daily lessened.

At R. L. + 227·00, the masonry of the dam will be up to the level of the bottom of the flume, so that from a few feet above that level, the flume will cease to be useful in keeping the work free from water. But at R. L. + 229·00 a culvert of 3 span for the turbine is to be introduced, which will practically take the place of the flume in dicharging the river water.

At this level the under-sluices will have increased in their discharging capacity up to 1,360 c. ft. per second under the increased head. The velocity through the sluices will then be about 21·25 feet per second and it would be advisable at that level to regulate the discharge through them, entirely closing them when there is a greater head than 47 feet over their sills.

Thereafter, whenever the under-sluices are not able to dispose of the water coming down the river, it must be passed over the work itself, and construction proceeded with in sections.

It is intended, however, after the masonry reaches about R. L. 240·00 to pass all the water, or as much of it as possible, over the bare rock towards the right flank of the dam, so as to avoid the severe shocks of a clear over-fall of from 50 to 100 feet over the new masonry of the dam into the deep bed of the river. This may not be invariably possible, but may be striven for by keeping the height of the masonry on the left flank and across the deep bed well in advance of that towards the right flank.

General arrangement at work-spots.

The position of the surplus flood escapes which can only come into use on completion of the dam to its full height is also shewn on the drawing No. 3.

The position of the mortar mixing machines is arranged near to the work site; they will be driven by a turbine which obtains its motive power from the flume. Close alongside the mortar mills, the platform for the mixing of the concrete is arranged.

The tramway from the stone quarries is divided into several branches at one end of the mixing platform and the stone delivered by tipping out of the waggon. The tramway sidings are elevated on posts about 6 feet above the mixing platform, so that after the broken stone is tipped from the waggons it falls down clear of the wheels and the rails, and the waggons may be immediately removed to make room for others.

On the side of the mixing platform far from the tram-line another tram-line will be laid by means of which the mixed concrete may be conveyed to the work site. As the waggons stand on this line, their tops will be on a level with the mixing platform so that the mixed concrete need only be raked into the waggon as a final operation of mixing.

probably To ensure the thorough mixing of the broken stone and mortar on the 1 to 1·04 or [illegible]form, it will be divided by balks of wood into parallel zigzag partitions, [illegible]ch of which, the mixers having received the stone and mortar in

In the year 18[illegible]d to turn them over and over towards the other end, on The velocity was a[illegible]tained have become thoroughly mixed and will be merely ascertained to be 3[illegible],000 c. ft. per

The water required in the process of mixing will be obtained from a tank supplied by a pump worked by the turbine through a pipe and tap.

On the facility and rapidity of these operations and freedom from breakdowns the quality, rapidity and successful construction of the dam will depend. It is hoped that with good arrangement, 6,000 c. ft. a day will be mixed and rammed.

The drawing shews the position of the stone quarries to which the tram-line is to be laid. A considerable quantity of the stone will also be obtained from the rock excavation of the head-sluice site and the channel in rear.

The lime kilns are marked at a convenient spot.

The surkee manufacture will unavoidably be conducted at Miloney a distance of about one and a half miles as no suitable clay could be found at a nearer place. A tramway will be laid to bring up the stuff.

On the plan are also shewn the work-shops, saw mills, stores, coolie-lines, hospital and the quarters for the staff.

Rate of progress.

A forecast of the rate at which the work of construction of the dam may be hoped to proceed is given in the following table.

Contents of masonry in the dam at various levels (approximate estimate.)

Section.	Reduced level.	Length of dam.	Width of dam.	Area in sq. feet.	Contents of section in c. ft.	Total in c. ft.	Approximate No. of working days at 6,000 c. ft. a day.	Remarks.
1	+ 192	100	79	7,900	88,130	88,130	14·7	At the early part of the work, the rate of progress will be slower than is shewn here, as extra care is required at that stage.
2	+ 199	240	72	17,280				
3	+ 207	330	64	21,120	1,53,600	2,41,730	40·3	
4	+ 220	460	52	13,920	2,92,760	5,34,490	89·1	
5	+ 227	480	46·4	22,272	1,61,672	6,96,162	116·1	
6	+ 234	700	41·2	28,840	1,78,892	8,75,054	145·9	
7	+ 254	860	28·8	24,768	5,36,080	14,11,34	235·2	
8	+ 264	1,130	22·8	25,764	2,52,660	16,63,794	277·3	
9	+ 274	1,200	17·2	20,640	2,32,020	18,95,814	316·0	
10	+ 284	1,350	13·6	18,360	1,95,000	20,90,814	348·5	
11	+ 294	1,400	12·0	16,800	1,75,800	22,66,614	377·8	
12	+ 296	1,450	12·0	17,400	1,71,000	24,37,614	406·3	
	302	1,550	12·0	18,600	1,80,000	26,17,614	436·3	

V. DISTRIBUTION.

i. General description.

Channels enumerated.

Distribution will be effected by two channels, one taking off from the right, and one from the left flank of the reservoir dam. Please refer to drawing No. 1. For ease of reference the one is called the left bank channel, and the other the right bank channel.

The left bank channel ends at its junction with the Paralyaur at the Puthen dam. In connection with the supply that is there delivered, the following new channels will be excavated.

The Tiruvancode channel.
The Eratakarai channel.
The Parakai channel.
The Anandanaur extension.
The Tovala channel.
The Attur channel (yet to be investigated).

The right bank channel proceeds as far as Parachalai, there splitting up into various smaller distributaries.

Areas under each channel.

The following table will shew the areas of new land to be supplied and old land to be aided under each channel.

Name of main channel.	Name of distribution channel.	Old cultivation to be aided.	New cultivation to be supplied.	Remarks.
Left bank channel.	Tiruvancode	...	6,200	The area given under Attur channel is only roughly estimated as the investigation as to the feasibility of the channel or the extent of the country it will serve is still undisposed.
	Eratakarai	...	1,120	
	Parakai	...	900	
	Anandanaur extension ...	...	1,700	
	Tovala	...	7,100	
	Attur	...	5,000	
	By existing channels ...	25,500	1,200	
		25,550	23,220	
Right bank channel	... ...		16,780	
	Totals.....	25,550	40,000	

Duty of the water.

In the table on page 18, shewing the reservoir capacity, sufficient water for the whole area was calculated as being impounded at a rate of demand of 1 c. ft. to 45 acres. This amount is excessive, but was so assumed in order to be on the safe side. In designing the irrigation channels, the rate will be taken at what it may reasonably be expected to be, namely 1 c. ft. to 60 acres and so avoid unnecessarily large and costly channels.

Loss by evaporation and absorption.

Evaporation and absorption are also to be considered in designing the sections of new channels of considerable length. The loss of water in that way is sometimes very considerable until the soil becomes staunched with silt. The actual loss will depend on the nature of the soil, the depth of water in the channel, temperature &c. In one recorded instance of a canal in the Bombay Presidency, the loss by evaporation and absorption in the first ten miles was 50 per cent. This is of course an extreme case. On the Nira canal (Bombay) the loss in 100 miles of length was at the rate of 1 c. ft. per second per mile or about 22 per cent of the whole quantity admitted at the head. Experiment made on Punjab canals of about 50 miles in length gave a loss varying with the time of the year from 12 to 14 per cent.

A masonry work across the channel is designed to effect this.

Its face wall is built up to R. L. + 243·00 which gives a sufficient margin above the M. F. L.

As the Paralyaur floods are very sudden and may occur at night, the design is provided with swing gates, which will close automatically immediately the level of the water in the river rises above the level of the water in the channel, but as soon as it falls, they will open again to allow the channel water to pass onwards. This automatic arrangement will remove any anxiety that would always be felt with a design requiring to be operated by a staff of lascars whose vigilance is always an unknown quantity.

As soon as these flood gates are closed by the superior height of the river flood water, and as long as they remain closed, the channel water will not be able to find an exit by the usual way, and would rise and overtop and breach the banks of the channel, unless some means for its escape is provided. The design therefore provides a surplus weir or escape from the channel leading into the Paralyaur below the Puthen dam.

As the ordinary water level in the channel could not be permitted to rise more than 1 foot without endangering the safety of its banks an escape of the ordinary fixed masonry crest type would have to be very lengthy and would be proportionately costly.

The design reduces this to very moderate limits by employing the moveable weir principle, the falling shutters of the same type as those for the reservoir escape being adopted.

iii. Tiruvancode channel.

Off-take of channel.

The supply for this channel will pass down the existing Pulpanabhapuram Puthenaur as far as 5 miles 200 feet where it will take off into the new Tiruvancode channel.

Length and profile.

The length of the new Tiruvancode channel will be 21 miles and 4,600 feet.

It will have a bottom width of 10 ft., at head, a depth of 4 ft. and a fall of $1\frac{1}{2}$ ft. per mile. Such a channel will discharge 111 c. ft. per second which will be sufficient to serve 6,200 acres at 1 ft. per second for 60 acres. The bottom width and depth will of course decrease as distributaries take off.

Description of channel.

Of these 6,200 acres 3,100 consist of lands already under rain-fed irrigation and 3,100 will be entirely new land.

The country through which the channel passes, presents no great engineering difficulty, except in the 6th mile, where it has to pass through a high saddle (known as the Tiruvancode saddle) the greatest depth of cutting being about 42 ft.; and again at the 7th mile, through another saddle called the Mulagamode saddle with a greatest depth of cutting of 63 ft.

Careful trial pits have been taken at points in these two saddles and it has thus been ascertained, that rock will not be met with, but the soft decomposed water-bearing rock stratum, with which so much difficulty has been experienced at Colasagaram saddle, occurs in both cuttings. The estimate therefore provides for concrete culverts through these saddles as open cuttings will be risky and difficult.

Cross drainage.

There is but one cross drainage of any importance: the Parayan kál. It will be passed under the channel by a masonry under tunnel of the type designed for the left bank channel.

The minor drainages are disposed of by simple culverts.

Regulators.

The head of the channel is provided with a regulator to control the water flowing down the Palpanabhapuram Puthenaur. At various points in the length

of the channel there will be small escapes for the disposal of any surplus flow that may be caused by heavy local rain or otherwise.

The necessary irrigation sluices for distributaries are also provided.

Bridges.

Wherever public roads are crossed the necessary bridging is provided as also foot bridges for passengers and cattle traffic.

iv. Eratakarai Channel.

There at present exists a short channel of this name 1 mile 2,200 feet in length taking off in the 17th mile of the Padmanabhapuram Puthenaur which supplies it. It is intended to improve this existing part and extend it to 6 miles 1500 feet. The channel is designed to carry 22 cubic feet per second.

There are several small masonry cross drainage works and masonry drops to be provided. All the works however are of a simple description.

v. Anandanaur Extension.

The supply for this channel will pass down the existing Anandanaur and Anandencolam channel. These will require no alterations.

The length of the new channel will be 5 miles. It will have a bottom width at the head of 4 feet diminishing to 3 feet a depth of 3 feet and a fall of 2 feet per mile.

The country through which it passes is flat with a gentle slope towards the sea. The construction will therefore be very simple with very little in the way of masonry works for cross drainages, drops, bridges, &c.

It is expected that this channel will bring under cultivation 1,700 acres of fresh land.

As the soil is somewhat loose and friable and the area comparatively small the channel has been designed to deliver 35 cubic feet per second.

vi. Parakai Channel.

No special description of this is needed.

It is a simple and short extension of the existing Parakai channel towards the sea in easy country.

vii. Tovala Channel.

Offtake and description of channel.

The Tovala channel will take off from the Pandian channel at 1 mile 3,800 feet from its head. Its length will be about 32 miles. It will have a fall of 2 feet per mile, 12 feet bottom width and 4 feet depth, and will be capable of discharging 158 c. ft. per second, sufficient to irrigate the 7,100 acres. Of this area 3,000 acres are existing rain-fed lands, 3,700 acres are entirely new lands, and 410 acres are lands now irrigated from the Palayaur system through the Chellamturuthy kál which kál will be absorbed by the new channel and these few acres will have therefore to be supplied.

The channel will pass through a somewhat difficult country in part of its length; the first 5 miles as far as Thadikaranconam will be in side long fairly easy country. The next four miles will be in very difficult and rocky country, which will very greatly enhance the cost of construction of the channel. Then for a length of 3 miles the country is level and easy. After this for a distance of 6 miles, rocky spurs are encountered, which will necessitate costly blasting operations. Thence for 14 miles to its end, the channel will pass through comparatively level easy country free from rock.

Cross drainages.

The cross drainages of importance are four in number—namely.

1. The Thadaviaur.
2. ,, Olakarayaur.
3. ,, Alathorayaur.
4. ,, Poiygayaur.

The first three of these are rivers and occasionally come down in sudden and very heavy flood—so that ample water-way has to be provided for them under the channel.

Aqueducts of 410 feet and 210 feet and 100 feet in length are required for the Thadaviaur, the Olakarayaur, and the Alathorayaur respectively.

The last of the rivers, the Poiygayaur, is crossed in flat country at about the same level as the river bed itself. It will not be convenient to pass it under the channel. It is therefore admitted into the channel, and when heavy flood occurs it will find its way out over an escape provided in the right bank for the purpose.

Regulator.

At the head of the channel a regulator will be constructed. A masonry regulator will also be built across the Pandian channel just below the off-take so that the quantities of water passing down the Pandian channel and the Tovala channel respectively may be correctly adjusted.

The usual distribution sluices are provided.

viii. The Attur Channel.

This channel has not yet been fully located. Investigation is in progress.

A ridge of high and rocky ground runs from the Paralyaur river above Tiruvettaur in the direction of Maycode thence it turns eastwards follows the Vallyaur as far as Tiruvancode and proceeds by Mulagamode nearly up to the sea at Tengapatnam.

The existence of this rocky ridge is the cause of delay in locating the channel. It had been hoped that it might be crossed at one of various points by an offtake from the Tiruvencode channel, but after careful examination none have been found feasible. It is now probable that the land will have to be served by an entirely independent channel taking off from the left bank channel in its 7th or 8th mile crossing the Paralyaur at Tiruvettar and proceeding thence via Attur.

The channel is shewn roughly in the irrigation map but the areas that it will command obviously cannot yet be indicated on it.

ix. Right Bank Channel.

Description.

This is the most important channel under the project, as it is expected that 16,780 acres of new land will be supplied. Of which, 7,000 acres is existing rain-fed area, and 9,780 is new land anticipated to be brought under wet.

This will require 280 c. ft. per second, and to convey this quantity the channel will be made of a bottom width of 19′, a depth of 5 feet and a fall $1\frac{1}{2}$ feet per mile: decreasing to a bottom width of 16 ft. in the 11th mile and 14 ft. in the 16th mile. The country passed through was found unusually difficult in the operation of locating the channel. Its first 6 miles traverses an unhealthy and entirely unexplored and unmapped country covered with close jungle. The operation of locating a good alignment was extremely difficult and tedious and the staff suffered severely from fever. The alignment, however, eventually decided on, is good, and will not be costly. After the 6th mile and up to the 10th mile, the country is also forest land, and partly unexplored. In this portion there is rock, but any extensive rock work is avoided. From the 10th to the end, or 22nd mile, it is in comparatively open, but broken, country involving a rather tortuous alignment in laterite side long ground.

At the 22nd mile the main channel breaks up into 3 distributaries, one passing down the right slope of the Parachalai yella, as far as Puvar, one passing down the same yella on the left slope up to Kollencode, and the last passing by Kallikavelai down the Mincherra yella. There will be a similar system of distribution channels from the main channel to the many minor yellas.

Cross drainages.

The chief cross drainages.

1. Vulliar yella.
2. Chittaur No. 1.
3. Chittaur No. 2.
4. Tenganbudur yella.
5. Yedamalai ravine.
6. Manur yella.
7. Mulliaur.
8. Yeddacode yella.

Of these, the following,

Vulliar yella,
Tenganbudur yella,
Yedamalai valley,

will be crossed by earthen banks with sufficient under-culverts to pass upland drainage.

The two Chittaurs and the Mulliaur being rivers of some size will have to be crossed by means of aqueducts. So also will the Yedamalai ravine which is a precipitous but narrow ravine with its bottom about 80 feet below the bed of the channel. The Manur yella is the most difficult and costly untertaking on the channel: the deepest point of its bed is about 80 feet below the channel bed; the channel will be carried across it in a timber flume supported on treatling.

Regulators.

The head-sluices are of a special design and have already been described. The usual sluices will be provided to the distributary channels.

Provision is made for disposing of any surplus water that may find its way into the channel.

APPENDIX I.

TABLE No. I.

AREAS AND CAPACITIES OF RESERVOIR AT VARIOUS LEVELS.

Reduced Level.	Depth in feet.	Area.		Capacity.		Remarks.
		In Sq. Miles.	In Millions of Sq. ft.	In mills. of C. ft.	In mills. of C. yds.	
207						
224	17	0·23	6·36	36·04	1·34	
234	27	0·58	16·04	144·36	5·35	
244	37	1·08	30·02	370·25	13·71	
254	47	1·73	48·23	755.60	27·99	
259	52	1·99	55·48	1014·87	37·59	
264	57	2·27	63·29	1311·79	48·59	
269	62	2·57	71·65	1649·14	61·08	
274	67	2·88	80·29	2028·99	75·18	
279	72	3·21	89·49	2453·44	90·50	
284	77	4·01	111·80	2956·67	109·80	
289	82	4·89	136·33	3576·99	132·48	
294	87	5·87	163·66	4326·99	160·26	
295	88	6·08	169·70	4493·67	166·43	
296	89	6·29	175·75	4666·40	172·83	
297	90	6·51	181·80	4845·18	179·45	
298	91	6·73	187·85	5030·01	186·30	
299	92	6·95	193·90	5220·89	193·37	

TABLE No. II.

GAUGED DISCHARGE OF KOTHAYAUR IN MILLIONS OF CUBIC YARDS.

1862-85

Months.	1882	1883	1884	1885	Average for 4 years.	Remarks.
January	98·33	31·21	7·19	23·65	40·09	The years 1884 and 1885 were unusually dry years.
February	17·94	45·47	1·03	3·24	16·92	
March	7·19	27·43	1·17	1·17	9·24	
April	11·79	42·12	0·57	1·14	13·90	
May	12·18	118·35	7·19	7·19	36·23	
June	195·42	203·64	1·14	248·70	162·23	
July	319·39	269·82	50·34	111·32	187·72	
August	391·74	118·35	39·74	118·35	167·04	
September	121·23	48·72	64·71	48·72	70·87	
October	98·33	170·34	118·35	118·35	126·34	
November	30·21	329·85	173·73	95·16	157·24	
December	98·33	85·52	98·33	50·34	83·13	
Total.....	1402·08	1490·82	563·52	827·33	1070·95	

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I.

DISCHARGE THROUGH THE UNDER SLUICES WITH DIFFERENT HEADS.

Assuming that they will discharge with a clear overfall

(*a*) to find discharge with water at R. L. + 220·0,

$A = 2 \times 4 \times 8 = 64$ sq. ft.

$V = c\sqrt{2gh.} = \frac{5}{8} \times 8\sqrt{9} = 15$ ft. per second.

$D = A. \times V. = 64 \times 15 = 960$ c. ft. per second.

(*b*) To find discharge with water at R· L. + 229·0,

Similarly,

$D = 64 \times 5 \times \sqrt{18}$

$= 320 \times 4{\cdot}25$

$= 1360$ cft. per second.

(*c*) To find discharge with water at R. L. + 254·0,

Similarly,

$D = 320\sqrt{43} = 320 \times 6{\cdot}58$

$= 2106$ c. ft. per second.

NOTE.—These will unwater the reservoir from R. L. + 254 to R. L. + 207 in about 6 days.

II.

DISCHARGING CAPACITY OF THE HEAD SLUICE.

I. Vertical Vents, 5 in No. each 4′ wide by 6′ high at R. L. + 254·00

To find depth of water on sill, the shutters being raised clear of the Vents.

(*a*) Discharge required being taken as 430 c. ft. per second.

$D = c\sqrt{2gd.} \times 1\ (dd + \frac{2}{3}d)$

i. e. $430 = {\cdot}75 \times 8 \times \sqrt{d} \times 20\ (4{\cdot}5 + \frac{2}{3}d)$

$= 540\sqrt{d} \times 80\ d\sqrt{d}$

where,
d = difference of water levels
dd = depth on lower side = 4′ 6″
c = ·75

i. e. $8\ d\sqrt{d} + 54\sqrt{d} = 43$

$d = {\cdot}56$ ft. or 6·7 inches approximately.

Depth of water on sill to give the discharge = 4·5 + ·56 = 5·06 ft.

(*b*) Discharge required being taken as 525 c. ft. per second.

By the same formula, d d being 5 ft. in this case, $8\ d\sqrt{d} + 60\sqrt{d} = 52{\cdot}5$.

$d = {\cdot}65$ ft. or 7·8 inches, approximately.

Depth of water on sill to give the discharge = 5·65 ft.

II. Horizontal Vents, at R. L. + 271·00 and at R. L. + 284·00.

There are 10 of these, 4′ × 4′ at + 271 and 10, 4′ × 4′ at + 284.

To find the head on the respective sills,

(*a*) Discharge being taken as 430 c. ft. per second.

$D = c.\ A\sqrt{2gh}$ where c = ·7

i. e. $430 = {\cdot}7 \times 160 \times 8\sqrt{h}$

$\sqrt{h} = \frac{43}{89{\cdot}6} = {\cdot}482$

$h = {\cdot}23$ ft. or 2·8″ approximately.

(*b*) Discharge being taken as 525 cft. per second.

By the same formula

$\sqrt{h} = \frac{52{\cdot}5}{89{\cdot}6} = {\cdot}59.$

$h = {\cdot}35$ ft. or 4·2 inches approximately.

III.

LENGTH OF ESCAPES.

Assuming crest of escape to be R. L. + 296·00.

Max. R. F. L. to be R. L. + 301·25.

i. e. a depth of 5·25 ft. on crest

(*a*) to find length to discharge 39,000 c. ft. a sec.

$L = \frac{D}{3{\cdot}25 \times h^{\frac{3}{2}}}$

$= \frac{3900}{3{\cdot}25 \times (5{\cdot}25)^{\frac{3}{2}}}$

$= \frac{39000}{3{\cdot}25 \times 12{\cdot}075} = \frac{39000}{39{\cdot}24}$

$= 994$

or 1000 ft. approximately.

(*b*) to find discharge on the above length with a head of 4′ 6″ on crest.

$D = 3{\cdot}25 \times 1000\sqrt{(4{\cdot}5)^3}$

$= 3250 \times 9{\cdot}54.$

$= 310000$ c. ft. per second.

IV.

FALLING SHUTTERS.

Escape: Pachiparai dam.

Across the Kothayaur.

Calculation for the height of pivots.

The shutters are 3′ 4½″ in ht. and subject to water pressure throughout the full height.

$h = \frac{2\ (a^3 + b^3)}{3\ (a^2 - b^2)}$

$x = \frac{M}{\frac{1}{2}\ (a + b)\ (a - b)\ 62\frac{1}{2}}$

h = head of water such that the pressures on either side of the pivot, are equal.

a = depth of shutter above pivot.

b = depth below pivot.

x = additional head required to overturn the shutter.

M = Force per foot run applied at a level of 1 foot above the pivot tending to overturn it.

= roughly 80 lbs., for the curved plate pattern shutter.

(1) Trial for $a = 25{\cdot}5$, $b = 15{\cdot}$ } Total head required above shutter to overturn ... ...is 16·2 inches.

(2) Trial for $a = 25{\cdot}$, $b = 15{\cdot}5$ } Do. ...is 20·1 inches.

(3) Trial for $a = 25{\cdot}25$, $b = 15{\cdot}25$ } Do. ...is 18·01 inches.

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Working for this 3rd trial is given below:

$$a = 25{\cdot}25 \quad \left\{ \begin{array}{ll} a^3 = 16098{\cdot}453 & \} \; a^2 = 637{\cdot}56 \\ b^3 = 3546{\cdot}576 & \} \; b^2 = 232{\cdot}56 \end{array} \right. \quad b = 15{\cdot}25$$

$$a^3 + b^3 = 19645{\cdot}029 : \quad a^2 - b^2 = 405{\cdot}00$$

$$h = \frac{2\,(a^3 + b^3)}{3\,(a^2 - b^2)} = \frac{39290{\cdot}058}{1215} = 32{\cdot}34 \text{ Inches.}$$

$$x = \frac{80}{\frac{1}{2} \times 3\frac{3}{8} \times \frac{5}{6} \times 62\frac{1}{2}} \text{ft.} = \frac{80 \times 12 \times 2 \times 8 \times 6 \times 2}{1 \times 27 \times 5 \times 125} = 10{\cdot}92 \text{ inches.}$$

From the above, it is seen that the head required to produce equal pressures on both sides of the pivot $= h - a = 7{\cdot}09$ inches, and the total head to overturn $= h - a + x = 18{\cdot}01$ inches.

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Copy of demi-official letter dated 15th September 1899 from the Diwan of Travancore on the subject of the Kodayar Project:-

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Referring to the last para of Mr. Rees' D.O. of the 16th August 1898, I beg to forward herewith the plans and estimates for the revised Kodayar Project received from the Chief Engineer. A printed report on the scheme submitted by Mr. Jopp is also forwarded. It will be observed that, when this report was prepared, estimates were complete only for the dam, headworks and the main channel up to Paralayar and the figures entered in the report for the distributory channels were only approximations. The estimates for the channels noted at foot have been subsequently received and it is observed that, though there are variations between the figures for the several channels entered in the report and the actual figures of the estimates, they do not materially affect the total cost of the scheme which is Rs. 27,05,450 against Rs. 27,00,000 mentioned in the report. A copy of the Chief Engineer's letter No.451 dated the 24th March last explaining the variations is also enclosed.

2. The bed of the reservoir which will be formed by the dam is covered with secondary forest and thick undergrowth which must be cleared prior to the submergence of the area. No estimate has been submitted for this necessary work. Mr. Jopp, however, calculates that the cost would be a lakh of rupees.

3. Thus the total estimatedcost of the scheme comes to Rs.28,05,450.

4. Mr. Jopp has in his report dealt somewhat fully with the history of the project and has indicated the circumstances which led to a revision of the original scheme. The latter scheme, prepared by the late Chief Engineer, Mr. Jacob, embraced the construction of a masonry dam 505 feet long and 73 feet high and a diversion channel up to Paralayar. The cost of these works was estimated at Rs.7,94,850. The Project was intended primarily to ensure an efficient supply to the existing irrigated area in Nanjenad and Edanad (23,367 acres) and secondarily to bring under

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plans and

irrigation a fresh area of 15,000 acres. No provision, however, was made in Mr. Jacob's scheme for the construction of channels to convey water to the additional area.

5. The Diwan Peishkar, Padmanabhapuram, to whom Mr. Jacob's scheme had been referred for an expression of opinion pointed out that there were considerably more than 15,000 acres of land capable of being brought under irrigation and suggested the expediency of revising the scheme so as to benefit the largest possible area. He estimated the area that could be newly brought under irrigation at 52,000 acres. After some correspondence, Mr. Jacob agreed to revise the Project so as to raise the ultimate height of the dam 5 feet more than was originally designed. He was accordingly asked to start work and submit a revised estimate. The work was started: but the revised estimate was not submitted.

6. In April 1896 Mr. Jopp inspected the works and submitted a report in which he pointed out several defects and advised a careful consideration of many important points connected with the scheme. Mr. Jopp was of opinion that the design of the dam required modification, and that there was no objection, from an engineering point of view, to considerably rasing the height of the dam and thus forming a reservoir capable of holding a supply of water which would irrigate a much larger area of land than was contemplated by the original scheme: and he suggested that an expert be consulted before proceeding further. Mr. Jopp was accordingly authorised to consult Mr. Walch, the late Irrigation Chief Engineer of the Madras Government, who, as acting Chief Engineer of this State, had also some local knowledge. Mr. Walch expressed his concurrence generally in the views and proposals of Mr. Jopp. Mr. Jopp was accordingly authorised to go on with the work as modified by him and to submit regular plans and estimates. on the designs

7. The work has accordingly been going on - the expenditure up to end of last Malabar year being Rs. 11,16,475.

8. With the printed report, as already observed, Mr. Jopp submitted complete plans and estimates only for the dam and its

appurtenances and the main left bank channel. The estimates for the distributaries were then in different stages of progress. The estimate for one of the minor channels (the Parakai channel) has not even now been received: and another channel (the Attur channel) has not yet been fully investigated and located. But these are comparatively minor channels and the non-receipt of full particulars regarding them need not delay the consideration and disposal of the scheme as a whole.

9. It is observed that no regular investigation had been made to ascertain the financial capabilities of the Project before work was started under the original as well as the revised schemes. In his report Mr. Jopp considered that an area of 40,000 acres would be newly brought under irrigation and assumed a uniform return of Rs.5 an acre. On the basis of these figures he calculates that the Project would yield a return of 8.2 p.c. on the capital expenditure, if the Project is completed in four years. Mr. Jopp, however, pointed out that the figures on which his calculations were based "are Engineer's figures, which the Government should get checked by the Revenue Department."

10. As the determination of the area that is likely to be brought under irrigation and the revenue which Government may reasonably obtain therefrom is an essential preliminary to the final consideration of the Project, a revenue investigation was ordered and a special officer was deputed for the purpose. He has just submitted the results of his investigation.

11. It is observed that, in the localities commanded by the Kodayar Project, according to the maps furnished by the Chief Engineer, an area of 55,269 acres can be newly brought under irrigation, besides the existing irrigated area (23,367) acres). The new lands consist of 15,983 acres of rainfed wet lands and 39,286 acres of dry lands and are distributed as under with reference to Taluqs.

Taluq	Rainfed wet land acres.	Dry land acres			Total of 2 & 5 acres.
		Registered	Unregistered	Total	
1.	2.	3.	4.	5.	6.
Thovalai	3,830	2,094	16	2,110	5,940
Agasteeswaram	580	8,645	,,	8,645	9,225
Kalkulam	4,079	6,826	639	7,465	11,544
Eraniel	1,954	9,211	9	9,220	11,174
Vilavankod	4,401	9,796	618	10,414	14,815
Neyyattinkarai	1,139	1,373	59	1,432	2,571
Total	15,983	37,945	1,341	39,286	55,269

12. Distributed with reference to channels, the area stands thus:-

Channel	Rainfed wet land acres.	Dry land acres			Total of 2 & 5 acres.
		Registered	Unregistered	Total	
1.	2.	3.	4.	5.	6.
Thovalai channel	4,393	9,750	47	9,797	14,190
Anandanar Do.	79	1,989	,,	1,989	2,068
Parakai Do.	,,	208	,,	208	208
Erattakara Do.	266	771	1	772	1038
Thiruvankod Do.	3,695	10,733	8	10,741	14,436
Attur Do.	244	682	,,	682	926
~~Right~~ Bank Main..	5,540	11,169	677	11,846	17,386
Left Bank Main..	1,766	2,344	607	2,951	4,717
*Existing irrigation channels.	,,	299	1	300	300
Total	15,983	37,945	1,341	39,286	55,269

* If water is available, this dry area of 300 acres can be turned into irrigated wet land, the existing irrigation channels being probably sufficient to irrigate them.

13. The special officer who conducted the Revenue investigation (Settlement Assistant Mr. Venkataswara Aiyar) estimates the return which would accrue from the above area, when brought under irrigation at Rs.2,31,686. The subjoined statement shows how this figure has been arrived at:-

Rainfed lands		Dry Lands.							Total of 2,8&9.
area. acres	water-cess Rs.	area acres	Dry assessment Rs.	Full or fallow wet assessment Rs.	Difference between 4&5 or additional fallow assessment. Rs.	wet assessment after making deductions on account of tanks Rs.	Difference between 4&7 Rs.	water cess Rs.	
1	2	3	4	5	6	7	8	9	10
15,983	*5080	39,286	15,634	453 183	4 375749	228 209	212576	14031	231 686.

* Excluding the present water cess of one fanam now realized on an area of 4000 and odd acres in Nanjenad.

14. In calculating the wet assessment, the settlement rates for similar lands in the settled taluqs have been adopted. Care has been taken to so fix the rates (tharam) as to make the assessment moderate. The water-cess has been calculated at 2½ fanams per acre - the rate adopted for the irrigated lands in the settled taluqs of Thovalai and Agasteeswaram. Now the so-called water cess charged on the irrigated area in Nanjenad is a nominal cess having no relation to the value of the water supplied. It does not represent even the cost of maintenance of the irrigation works. This light cess has been adopted in consideration inter alia of the rather heavy assessment imposed on wet lands in Nanjenad.

15. The enhanced assessment given in column (8) of the statement in para 13 is the ordinary wet assessment fixed without special reference to irrigation facilities - that is, on principles common to irrigated and non-irrigated taluqs. All lands on which paddy is grown whether they are irrigated or not by any Government work, are liable to wet assessment at one and the same rate which is considerably higher than that imposed on dry lands, i-e., lands on which green gram, horse gram or the like is grown. When these lands are regularly supplied by Government with water which will protect the crops against drought, it is nothing but fair to demand a higher water rate than the nominal cess levied on the area in Nanjenad. A uniform rate of one rupee an acre outside the existing irrigated area seems to be moderate. This would make the aggregate assessment (including the water rate) on each acre of new land Rs.6.4 per annum by no means a heavy burden. In British India the standard water rate, I believe, is Rs.4 per acre on first crop and Rs.2 on second crop, or Rs.6 per annum, exclusive of the dry assessment on the land. In the settled taluqs of Nanjenad (Thovalai and Agasteeswaram) the average wet assessment is Rs.14 per acre, or after making deductions on account of favourable tenures Rs.9¼ per acre. This average relates to the whole area - irrigated and unirrigated - In the shape of new water cess on irrigated wet lands in Nanjenad

no fresh returns could, under these circumstances, be expected.

16. In calculating the financial capabilities of the project we have to take into consideration two other items viz., (1) the annual remissions of revenue on account of failure of crops: and (2) the amount now spent in the construction and improvement of irrigation tanks in the Southern Division.

17. The amount of land revenue remitted on account of failure of crops in the taluqs of the Southern Division during the last 15 years comes to Rs. 9,18,608 which gives an average of Rs. 61,000 a year. After the completion of the project about ⅔ of the existing wet area will be commanded by it: and without ignoring the fact that, in years in which monsoons totally fail, the project itself may not be able to render sufficient help, we may reasonably presume that failure of crops will be less likely and be less frequent and less pronounced than now. We may, therefore, take Rs. 45,000 as probable savings to Government under the head of remissions.

18. The expenditure on account of tank restoration in the taluqs of Thovalai, Agasteeswaram, Eraniel, and Kalkulam during the ten years - 1064 to 1073 - amounts to Rs. 5,17,680 or an average of Rs. 51,000 a year in round numbers. These tanks are intended to impound a portion of the drainage during the monsoons. Most of the tanks are so small and shallow that they only contain on an average 15 days' supply to the lands depending on them. Having regard to the capacity of the proposed Pachippara reservoir, the maintenance of these tanks would be unnecessary. At all events, the expenditure could safely be reduced to one-half. The saving on this account will be about Rs. 25,000 per annum.

19. The aggregate return from the project ultimately would stand thus:-

1. Enhanced land revenue	Rs. 2,12,5[illegible].
2. Water cess on lands which will be newly brought under irrigation	Rs. 54,641.
3. Savings on account of remissions.	Rs. 45,000.
4. Savings on account of tank works.	Rs. 25,000.
Total	Rs. 3,37,216.

Mr. Jopp calculates the cost of maintenance of the works at as.8

an acre. It is not clear whether this includes the cost of establishment. If it does, the annual expenditure on this account would be about Rs. 28,000. The net annual return would thus be Rs. 3,09,216 or three lakhs in round numbers.

20. From the table in para 11 above, it will be seen that unregistered Government wastes likely to be converted into wet lands, aggregate, according to the special officer 1,341 acres. These lands may be sold by auction. Mr. Jopp thinks that the cultivable waste lands may fetch Rs. 100 an acre. To be on the safe side, I would take Rs. 75. We may, therefore, take the sale proceeds of puthuval lands at one lakh of rupees. Information is not available as to whether any and if so how much of this area has been already applied for. As it is doubtful whether, in view of the provisions of the Land Conservancy Regulation, lands already applied for and occupied, though not registered, could be sold by auction, some deduction may have to be made in the above figure.

21. I have already alluded to the irrigation tanks and the possibility of reducing the outlay on their maintenance. With the certain and perennial supply which the project is expected to ensure, most of the tanks could well be converted into paddy lands, The area of tank beds could at any rate be considerably reduced. The area of the tank beds in the South amounts to about 13,500 acres. The area of the tank beds within the localities commanded by the project is approximately 12,000 acres. Assuming that 50p.c. of this area may be converted into paddy lands, we have 6,000 acres for disposal. The tank beds will form excellent paddy lands and if sold by auction would fetch on an average not less than Rs. 250 per acre. This will yield Rs. 15,00,000. The assessment on this area, taking the moderate figure of Rs. 5 an acre and water cess at one rupee an acre, would yield an annual return of Rs. 36,000.

22. Thus, in the aggregate, the project would yield a lump sum of about Rs. 16,00,000 and an annual return of Rs. 3,45,216. As the question, however, of reducing the area of tank beds can be

considered only after the project is completed and its capabilities known by actual experience, the estimated financial return in connection with the disposal of the tank beds may be left out of account for the present. Deducting this, we shall have a lump sum of about one lakh and an annual return of Rs.3,09,216 or in round numbers 3 lakhs, as already stated. This latter, when capitalised would stand thus:-at rates of interest varying from 3 to 12 p.c.

At 3 per cent.	Rs.100,00,000.
,, 4 ,,	,, 75,00,000.
,, 5 ,,	,, 60,00,000.
,, 6 ,,	,, 50,00,000.
,, 7 ,,	,, 42,85,714
,, 8 ,,	,, 37,50,000.
,, 9 ,,	,, 33,33,333.
,,10 ,,	,, 30,00,000.
,,11 ,,	,, 27,27,272.
,,12 ,,	,, 25,00,000.

23. Mr, Jopp's estimates amount to Rs.27 lakhs plus one lakh for clearing the jungle in the reservoir bed. The financial return would thus seem to represent about 10 p.c. on the outlay of 28 lakhs.

24. It should be remembered that the above return is calculated on the assumption that the whole of the 55,000 and odd acres will be brought under irrigation. Of the above area, 15,985 are precariously rain-fed wet lands which are suitable and ready to receive irrigation at once. In Travancore the use of irrigation water and consequently the payment of water rate are not left to the choice of the ryots. Irrigation water is supplied as a matter of course and not on the application of the ryots to all lands for which the supply is available and water rate is charged and recovered along with the assessment. Of the remaining area, (39,286 acres) capable of being turned into wet lands, provided water is available, it is not possible to say with certainty how much will be converted into such lands and within what time. Mr. Jopp gives it, as his opinion, that out of 25,000 acres (which was his estimate of the dry area fit for wet cultivation) about 21,000 or over four-fifths are situate on nearly level sites and only

about 4,000 acres are on slopes which require terracing. The former could be converted into wet lands without any considerable expenditure of labour and capital. Conversion of dry into wet lands, wherever facilities for such conversion exist, is a well-known feature especially in South Travancore. Mr. Jopp points out that in the areas commanded by the Kodayar channels, the soil is, as a rule, very suitable for paddy cultivation, leaf manure is plentiful and cheap, and the lands have excellent facilities for drainage. My predecessor (the Hon'ble Mr, Shanguarasubba Aiyar) who had considerable experience of South Travancore, observed in his letter to Mr. Rees No.1268 dated 6th April 1898: "The temptation on the part of ryots to convert dry into wet cultivation is largely prevalent in the South. It is water difficulty alone that stands in the way.....Every drop of water would only be greedily availed of for cultivation in a thirsty tract like South Travancore. If water could only be brought within the reach of every acre of land, the stimulus to agricultural industry and prosperity would be simply marvellous."

25. The following figures taken from the last census report would give an idea of the population of the tract commanded by the project.

Number	Taluqs	Total population	Average number of persons to a square mile.
1	2	3	4
1	Thovalai	29,751	245.87
2	Agasteeswarem	87,241	899.38
3	Eraniel	1,05,098	740.42
4	Kalkulam	59,474	418.83
5	Vilavankode	68,521	469.32
6	Neyattinkarai	1,10,755	519.97

The average density for the whole State is 580 per square mile. The census Commissioner observes: "The occupations by which the majority of the people subsist are connected with

agriculture.....The pressure of population is steadily increasing from year to year,.....I do not think the food-producing area has increased to the same extent." These observations apply specially to South Travancore-i.e., to the tracts commanded by the project.

26. I think, therefore, we may safely conclude that the conversion of the cultivable dry ~~duty~~ into wet lands, though necessarily a slow process, would actually take place and that, within a reasonable time after the completion of the project, a considerable portion of the dry area will be turned into wet cultivation.

27. Before proceeding to the engineering and other aspects of the scheme, I would deal with the financial prospect of the Right Bank Channel taken by itself, as it is specifically alluded to in the enclosure to Mr. Rees' D.O. above referred to.

28. From the statement in para 12, it will be seen that the area that is likely to be brought under irrigation under this channel is 17,386 acres - 5,540 acres of wet and 11,846 acres of dry land. The financial return from this area will be Rs.55,413 (enhanced land revenue) plus Rs.17,386 (water cess) plus Rs.2,775 (savings on account of remissions) or a total of Rs.75,574. To this should be added Rs.1,869 which represents half the average expenditure on irrigation tanks, the other half being, under existing arrangements, recoverable from the ryots. (This item being inconsiderable was not taken into account in calculating the return on the project as a whole.) Thus the aggregate financial return will be Rs.77,443 which represents about 17 per cent on the estimated cost of the right bank channel (Rs.4,60,000) It may be noted that, of the total unregistered wastes which may be sold by auction, 677 acres or about a half are in areas commanded by the right bank channel. This would probably yield a lump sum of about Rs.50,000.

29. As already observed, it is not possible to forecast with certainty the rate at which and the period within which the conversion of dry into wet lands will be effected. There is doubtless a considerable extent of

land suitable for irrigation. The population of the tract is sufficient to allow of a reasonably rapid spread of irrigated cultivation. The irrigable area lies within easy reach of the source of supply and in respect of a portion of it (that is, the lands which could be fed from the main left bank channel) irrigation is likely to spread almost concuurently with the progress of the works. But the conversion of dry into wet lands, especially in slopes which require terracing, involves an initial outlay for which the average ryot may not have either the means or the inclination. The estimates of the project have, no doubt, been prepared with due regard to local conditions, but in a larger undertaking like this unforeseen difficulties may arise, disturbing present calculations and necessitating additional expenditure. I must not omit to mention here that the estimates do not include the cost of making and maintaining many small channels for distributing water through large areas of varying levels and of the construction of aqueducts and bridges connected therewith and that this cost is not likely to be an insignificant portion of the expenditure on the whole project. Making allowance for all the circumstances indicated above I am disposed to think that a net return of 5 p.c. on the total possible outlay may be reasonably looked for.

30. On the engineering features of the project, I need not say much, as the subject is purely professional and has been dealt with fully in Mr. Jopp's report. The proposed dam is 115 feet high at its highest point in the bed of the river and 1525 feet in length along its crest. This is expected to form a reservoir covering an area of about 7 square miles. The head-sluices constructed on each flank of the main dam will be capable of drawing off water to a depth of 45 feet below the full supply level in the reservoir. One important and I believe novel feature of the project as now designed is the provision of under sluices at the base of the dam. Mr. Jopp points out that, under the existing system of irrigation in South Travancore, the under sluices "could not be put to use as silt-clearers." but they are

useful "to permit unwatering in case of necessity and to facilitate construction." As Stoney's patent roller gates, which are usually provided are costly, Mr. Jopp has adopted a design of his own which he describes in page 26 of his report. He has also adopted a novel design for the head-sluices and the escapes.

31. On the question of the capacity of the project also-i.e. the quantity of water which it can supply for irrigation purposes Mr. Jopp has furnished some detailed information in his report. His conclusion is that the reservoir, as designed, is capable of irrigating about 60,000 acres of new land. The area capable of being turned into irrigated wet lands is only about 55,000 acres. The existing irrigated area (23,367) acres) requires only a supplemental supply equal to about a fourth of the quantity required for an equal area of fresh lands. Thus the project may be reasonably expected to meet the demands of the existing wet cultivation and the possible future developement of such cultivation. The latter as already observed is necessarily a matter of slow process and it will be many years before the maximum will be reached.

32. The waters of the Paralayar are not fully conserved and utilised. There is at present a considerable waste of these waters. Mr. Jopp considers (vide pages 17-19 of his report) that this waste can be effectively prevented and that much of the water thus wasted could be diverted to the Pandian kal to supplement the existing supply. His Highness' Government cannot at least until the completion of the present project undertake any costly works in the Paralayar. The point, however, is worthy of note as showing the existence of a reserve of irrigation water in case the Pachippara reservoir fails to meet fully all possible future demands.

33. The Chief Engineer considers that the whole project should be completed in 3 years as the delay in the completion of the work would increase the capital cost by accrual of interest and would lead to the loss of the benefit of earlier revenue

return. Doubtless, other things being equal, speedier completion would secure greater economy: but Government have to weigh other considerations in determining the annual allotment. The outlay already incurred amounts to Rs. 11,16,475. According to the estimates (including the outlay for clearing the bed of the reservoir of jungle) an expenditure of Rs. 16,88,975 has yet to be incurred. In view of the policy which, after mature consideration, His Highness' Government have deemed it best to adopt, of meeting the expenditure from current revenues, the outlay, I think, will have to be spread over a longer period than is suggested by Mr. Jopp.

34. I think, I have dealt with the leading aspects of the scheme. The revised estimates have not yet been formally sanctioned by Government. In his letter No. 1287 dated the 18th ultimo (copy enclosed) Mr. Jopp points out that "the work has now arrived at a stage at which it is absolutely necessary that a definite decision be arrived at." Before passing final orders, His Highness' Government wish to have the benefit of your kind advice particularly with reference to the under-sluices, the head-sluices and the escapes for which novel designs have been adopted. I shall be much obliged by your kindly favouring me with your views at your earliest convenience. His Highness' Government have no objection to your consulting any expert on the subject, if you think such consultation necessary.

1. Thirvankod channel.
2. Erattakara channel.
3. Anandanar extension.
4. Thovalai extension.
5. Right bank channel.

(Sd.) K. Krishnaswami Rao.

S. T. Mackenzie

Ag Resident.

Ag Secy.

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