Irrigation commission

Report on Tungabhadra

1927

[May be lent out to M.L.C.S.]

(Report has been printed as an annexure to G.O. No. [illegible] of 12th [illegible] 1905, submitting plans & estimates for the Project to Govt. of India)

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2 Irrigation comm Report on Tungabhadra Project

IRRIGATION COMMISSION.

Note on the Tungabhadra Scheme by H. E. Clerk, Esq., Superintending Engineer on Special Duty, dated 7th January 1902.

The waters of the Tungabhadra are tapped by eight minor anicuts in Bellary district, but they only command a very small area of land. This is owing to the fact that the slope of the country towards the river is very rapid, while the fall of the river itself is small except in a few places. It is, therefore, impossible to get far away from the river. Below this are the head works of the Kurnool-Cuddapah canal at Sunkesala. The accompanying statement shows that during five months of the year a considerable quantity of water passes over the anicut and as at that time water is also passing over the Bezwada anicut there is no objection to its being used if possible.

2. Proposals for extending cultivation under the Tungabhadra have, for a long time, been discussed.

When the Madras Irrigation and Canal Company was inaugurated, the projects in view consisted of (1) a Bellary section, (2) the Kurnool-Cuddapah canal, and extension to Someswaram, (3) a Nellore section, (4) of supplementary reservoirs, chiefly in Mysore. Of these the Kurnool-Cuddapah canal alone was completed, and the results of that portion gave no encouragement for the prosecution of the rest. But the ravages of famine in the Bellary district could not but constantly revive the hope that a large irrigation scheme depending on the water of the Tungabhadra might yet, if not directly a pecuniary success, nevertheless bring in sufficient financial returns to prevent its being absolutely ruinous and to warrant its construction as a protection against famine, with the resultant mortality, suffering and expense. Consequently schemes for an upper and lower Bellary project, in forms extensively modified from time to time, have been under the consideration of Government for many years.

Vincent's monograph, paragraph 85, et seq.

The upper Bellary project (*a*) high level line consisted in taking off a canal from the Tungabhadra at Valvapur to irrigate 150,000 acres and at a sufficiently high level to supply Bellary town and cantonment with water. The length of this line was 66¾ miles to Bellary and thence 56 miles to the river Hagari. The supply through the head sluice was to be 2,250 cubic feet a second and the estimated cost Rs. 1,43,88,000, with a net return of Rs. 3,74,500, or 3·26 per cent. on *direct* charges, or 2·6 per cent. including maintenance and collection.

Vincent's monograph, paragraph 85, et seq.

The line taken by this canal would have involved very heavy cuttings as well as a considerable amount of tunnelling through rock, and the Government of Madras expressed an opinion unfavourable to its execution.

G.O., No. 1756 of 22nd March 1869.

There was also the difficulty that very little water is, in years of deficient rainfall, available for the Bellary district except during the flood season. The demands of the Kistna delta render impossible the supply for any further irrigation on a large scale from the Tungabhadra, unless by storage of flood water.

The above facts led to the consideration of another scheme, viz., the upper Bellary project (*b*) low level line. This consisted in taking a canal from the Tungabhadra at Hosur, which is 9 miles in distance and 60 feet in level below Valvapur, to carry 3,187 cubic feet per second and irrigate 212,500 acres. This canal would have passed about 2 miles from Bellary and considerably below it, affording therefore no supply to the station. The length to the first proposed terminus, 2 miles from Bellary, would have been 75 miles, the extension to the river Hagari involving an increase in length of 20 miles. The estimated cost was Rs. 1,65,24,640, with a return of Rs. 5,66,700, or 4·07 per cent. on direct charges, or 3·4 per cent. including maintenance and collection.

Vincent's monograph.

The same objection as regards water-supply applies to this as to the high level project, and though there was not so much heavy cutting, some very long retaining walls would have had to be built.

Altogether it was considered that both the high and low level schemes for a canal from the Tungabhadra in the Bellary district were very unpromising whether cost, result of outlay, or probability of successful irrigation were considered.

P.M.G., No. 210 of 28th December 1876.

Projects for lower Bellary were merely extensions of either the abovementioned high or low level lines and shared their disabilities.

The subject was revived from time to time, and in 1885 Mr. C. Norfor, who had been deputed to examine a project for the supply of drinking-water to Bellary station, submitted a "Preliminary Report" in which he advocated the investigation of the "Upper Bellary project" on a greatly reduced scale, which with certain remarks he was instructed to do. In 1886 the result was submitted. The then Chief Engineer for Irrigation considered that further investigation of short duration was necessary.

In 1889 Mr. A. S. Russell was deputed for further investigation and in that year submitted a "Preliminary Report" from which it was evident that it would take a long time to carry out all the investigations that he understood Government intended.

G.O., No. 521 I. of 29th October 1889.

The then Chief Engineer for Irrigation, Mr. G. T. Walch, thereupon made a personal inspection and reported to Government that, irrespective even of the sufficiency of supply from the river in bad years, the scheme was one on which it was inadvisable to spend more money in any way. His reasons were that for 18 miles out of 35 the canal would have to be taken along the slopes of rugged rocky hills such as form the distinctive feature of the Bellary district, over and through fields of boulders lying on shattered gneiss where no soil is available for banks and where the water must be retained by miles of continuous walling, and across ridges by cuttings of great depth and through hills by tunnels some three miles in length. The cost of overcoming these difficulties he considered it impossible to forecast, because not only would much of the work be of an unusual character but because it seemed likely that along the hill slopes, in the cuttings, and in the tunnels, the water would escape through the fissures and faults of the shattered gneiss, and thus necessitate lining the whole canal with water-tight masonry or cement. As the result of such expenditure, not less than Rs. 50,00,000, the most that would be possible would be the irrigation of 50,000 acres during six or seven months of the year, but it was extremely doubtful whether the land would be taken up for wet cultivation, the soil, the climatic conditions, the nature of the crops which find favour with the people, and the people themselves, being similar to those in the Kundar valley through which the Kurnool canal carries its volume of water almost unused.

G.O., No. 521 I. of 29th October 1889.

These views Government accepted.

G.O., No. 222 I. of 8th March 1899.

Mr. O'Connell reported in December 1897 and February 1898, but his investigation so far as it extended disclosed no new facts of importance material to the question, on which Government observed that the subject must not be dropped, since there was a vast quantity of water in the Tungabhadra running to waste which it was the duty of Government to utilise, if possible, in the interests of a district specially liable to famine. The investigation was therefore to be resumed without being confined to any particular site or channel.

Colonel Baddeley submitted a report with a note by Mr. H. E. Clerk on 5th November 1898.

These officers reported on three possible reservoir schemes on the Tungabhadra: (1) a reservoir within 12 miles of Hospet to irrigate Bellary and Alur taluks, (2) a reservoir somewhere west or south-west of Hadagaly to irrigate Hadagaly and Hospet taluks, (3) a reservoir at the best site on the river, from which water might be passed down and taken off by anicuts where most required. In regard to (1) and (2) they examined sites at Mallapur and Vallabhapur. The Mallapur site they described as good but with doubtful foundations and 34 villages (of which in the Nizam's territory) and a not inconsiderable quantity of irrigated land would be submerged, while at Vallabhapur also 34 villages (of which 19 in the Nizam's territory) would be submerged, so that irrespective of the serious objections to the destruction of so many village-sites and the opposition of the Nizam, the compensation in both cases would be enormous.

After again urging the cost and difficulty of the passage through the Daróji hills, Colonel Baddeley insisted on the unlikelihood of utilising the water, in which his personal experience coincided with the views of all the Revenue and Public Works officers who were familiar with the subject.

He further reported that between Bellahunsi and Hampaságaram there were sites nearly as good as Vallabhapur, but the fall of the river above Vallabhapur being slight no gain in command would be obtained and the Daróji hills would still have to be traversed and by a longer channel, while from Hampaságaram to Honnur the country was flat and there were no sites for a reservoir. At Honnur he considered that the schist and indurated clays forming the river-bed were unsuitable for the foundation of a dam. Above Honnur there were no reservoir sites.

With reference to the third alternative—of forming a reservoir and using the water where required from place to place along the river—he pointed out that the main utilisation would be near Cuddapah and in the Kistna delta, which were not in question.

He recommended in preference small reservoirs on tributaries, as numerous and widely scattered as possible, so as to have the largest possible catchments, the least possible submergence of villages and cultivated land, with greater facilities for the spread of irrigation in small areas; and he instanced sites at Hagaribommanhalli on the Chinna Hagari and near Honnur across a tributary of the Tungabhadra.

G.O., No. 222 I. of 8th March 1899.

The above report, the Government of Madras still considered, did not settle the matter, and directed the further examination of sites at Honnur, where the river passes through the Sandur hills, and at Valvapur, and the preparation, if either were found suitable, of a detailed

estimate for a reservoir. If both were found unsuitable a site was to be sought for on one of the tributaries of the Tungabhadra in Mysore. If a suitable site was found, an estimate was to be prepared in detail for a channel to irrigate 50,000 acres in Bellary east of the Daróji hills and as much land as it could command west of the Daróji hills.

In accordance with this Government Order, Colonel Baddeley once again reported that the only proper site for a reservoir was at Valvapur; since at Mallapur 39′ of command would be lost, and at Honnur the foundations were bad and the channel would be much longer, that the channel would, as previously described, be enormously difficult and would cost from 44 to 50 lakhs of rupees; that no appreciable area was irrigable west of the Daróji hills; that a dam at Valvapur to store 18,000 millions cubic feet would be $4\frac{3}{4}$ miles long and would cost from 84 to $100\frac{1}{2}$ lakhs of rupees; that a sum of quite 19 lakhs would be needed for compensation; that the minimum cost would therefore be 147 lakhs with a maximum gross return of $2\frac{1}{4}$ lakhs; and that even such small return was, he believed, quite illusory.

Vincent's monograph.

It only remains to summarise the information available regarding reservoirs on the tributaries of the Tungabhadra. While the Kurnool-Cuddapah canal was being constructed and the happy anticipation, that the Ceded districts could be converted into a large scale repetition of the great deltas, still existed, enquiries and surveys were made on a considerable scale concerning five sites for reservoirs on tributaries of the Tungabhadra out of twenty-one suggested. These five sites were—

(1) Maddak-Massur on the Choardy.
(2) Mudaba on the Tunga.
(3) Lakvalli on the Bhadra.
(4) Mari on the Hagari.
(5) Bajoli on the Tunga.

The fifth was soon rejected, as it was close to the second, which was superior. The fourth was also abandoned after long correspondence, as the other three were more favourable.

No. (1) site, with a drainage area of 500 square miles, was estimated to be capable of storing 37,800 millions of cubic feet with a waterspread of 40 square miles at a cost of 12 lakhs, or of storing 17,388 millions cubic feet with a waterspread of 24 square miles at a cost of $6\frac{3}{4}$ lakhs. The compensation in the latter case as assessed by the Mysore authorities was taken at 4·7 lakhs, but this was considered far too low, since the site included the bed of an abandoned native reservoir which had all been occupied.

No. (2) site, with a drainage area of 760 square miles, was estimated to be capable of storing 128,250 millions of cubic feet, with a waterspread of 13 square miles submerging many villages, depth of water 162 feet, length of surplus 1,523 feet with 6 feet overflow, this length not being obtainable; total cost 65 lakhs. This project was not considered feasible, as further the compensation demanded was 70·35 lakhs.

No. (3) site was considered best, the area of occupied land being small and the engineering difficulties much less. The drainage area was 760 square miles, and it was estimated that a reservoir of 31,075 millions cubic feet capacity could be constructed for $31\frac{1}{3}$ lakhs, or including establishment about 50 lakhs, *plus* a compensation estimate of 40·84 lakhs.*

3. It will be seen from the above that any extension of Tungabhadra irrigation must depend on storage and it has first to be decided on how the water is to be utilized. The original idea was to irrigate the Bellary taluk and this has first to be considered. A reservoir and channel for this purpose has been estimated by Colonel Baddeley to cost about Rs. 1,50,00,000,† while the prospects of the water being utilized in ordinary years are almost *nil*. The following are the reasons why irrigation would fail here :—

(1) The soil is stated to be unsuited to wet cultivation.
(2) The people of the country do not care for it and immigration is unlikely.
(3) Wet cultivation would not pay as long as there is no pressure of population on the soil.
(4) It would not improbably render the country unhealthy. The Commission will doubtless obtain further evidence on this point which I regard as a revenue and an agricultural rather than an engineering one and I will pass on to other means of utilising the water.

4. It is exceedingly difficult to make a forecast of what would happen if this project were carried out. I believe, however, that the result would be something of this sort—

		Lakhs of rupees.
Expenditure.		
Capital cost	...	200
Annual maintenance	...	2
Returns.		
10,000 acres permanent wet at Rs. 6	...	0·6
Once in five years $\frac{3,00,000 \times 2}{5}$ =	...	1·2
Total	...	1·8

* This history of the project is taken from a note compiled by the Assistant Chief Engineer for Irrigation.

† I believe this to be a low estimate and that Rs. 2,00,00,000 would be required.

The project would not, therefore, pay its working expenses. It would enable crops to be grown in times of scarcity and would in a large measure (but not entirely) protect the Bellary taluk and a portion of Rayadrug.

5. There are two places where the surplus water of the Tungabhadra could be conveniently utilised—

(1) In extending irrigation in the Kistna.

(2) In irrigating fresh tract of Nellore and possibly also a small area in Cuddapah.

6. As regards the supply to the Kistna, the best way to extend cultivation there would be the construction of the Kistna reservoir, regarding which Mr. Reid has submitted a note. In the event of its being considered that that reservoir is impracticable, I consider the best place to utilise any waters stored on the Tungabhadra would be in the Kistna district. Assuming the Kistna reservoir scheme to be accepted, we have to look to Nellore as the destination of any storage. It will be seen that the Kali, a tributary of the Pennér, rises close to the water-shed of the Tungabhadra in the Nandikotkur taluk and that the problem is how most economically to turn the waters of the Tungabhadra into that basin. The Kurnool canal already passes through the water-shed by a shallow cutting at the 75th mile, and is an obvious means of attaining the desired end. There are, however, difficulties in the way. In the first place, the canal is carried on a contour through difficult country and is 75 miles long when the cutting is reached. The banks and the soil on which the banks are founded are very porous so that there is an immense loss in percolation. From the 54th to 60th miles the canal passes through the Pagadiala and Tangadentza tanks, where the banks, although not very high, are continually giving trouble. There is a great deal of percolation here which leaves the ground in rear in a most dangerous condition. Much has been done by draining, but the soil is of so treacherous a nature that I do not think that the local officers would recommend any considerable raising of water level in the tanks.

The bed-fall of the canal in the first 75 miles is very slight, especially in the latter end of it; e.g., in the 65th and 66th miles it is only ·17 foot per mile. It would therefore be necessary to enlarge the canal very greatly if it were proposed to send down any large quantity of water.

7. There are two different ways in which storage can be effected—

(1) by the construction of a reservoir above the canal and passing down only so much of water as would be required for direct irrigation, and

(2) by largely increasing the capacity of the canal and passing down large quantities when available to be stored in Nellore. The latter method would, if practicable, be the best way of disposing of the question. There are numerous tanks in Nellore which can be commanded by a channel taken from an anicut at Somesila. This is the point chosen by the Irrigation Canal Company for their anicut and partially-sunk square wells of brick work are still in evidence at the site. A channel on the right bank taken about 20 feet above the deep bed of the river would run for about 30 miles in the basin of the Pennér, and from it all the tanks between it and the river as far as the Nellore tank could be commanded. The ridge into the Kandleru basin could be crossed close to Yotur tank and from thence the channel could be taken to command a large area of fertile land now cultivated with paddy.

Unfortunately there are not many large tanks. The united capacity of the existing [illegible] commanded as far as the Upputeru river is only a little over 2,000 millions cubic feet. [illegible] however, could probably be doubled [illegible] additional 4,000 millions cubic feet given [illegible] forming new tanks, making a storage of [illegible] millions cubic feet * or enough for 40,000 acres.

* Since writing the above I have received a report saying that good sites for reservoirs can be found on the Kandleru and Pinneru. The amount of storage capacity above mentioned is, therefore, probably understated.

8. In view of the fact that the opportunities for storing water in Nellore district are not so good as one could wish, it is worth considering whether the construction of a reservoir at Somesila would not be feasible. Some preliminary investigation of this scheme has already been made. The site, except so far as foundations are concerned, is a very suitable one. The river passes through a gorge, 1,200 feet in width, and a dam 60 feet above the deep bed of the river would hold up 10,000 millions cubic feet. This reservoir would fill several times in the course of the year and with the existing tanks it would be possible to irrigate at least 100,000 acres.

The principal difficulty would be with the foundations for the dam. Borings have been taken and show that hard rock is met at from 25′ to 30′ below the riverbed. The rock which forms the chain of hills here is quartzite and it is probable that the surface layers are much fissured. It is likely, however, that at a depth of 40 feet sound foundations could be formed. The surplus and the water required for irrigation lower down would be passed through vents in the dam. Such a work would be expensive, but if feasible would solve the question of storage in Nellore.

9. A reservoir at this site would have at its disposal practically all the surplus water of the Pennér, but as will be seen from the table of surplus discharges at page 173 of my report there is no certainty of water from the Pennér itself being available for storage until September and in some years such as 1891–92 the supply would fail. An earlier supply could be given from the Kurnool canal. This could be done on a small scale in the following manner :—

The upper reaches of the canal should be improved and strengthened. A contour channel should be made round the Pagadiala and Tangadentza tanks and the reach from the 61st to 75th mile should be widened and deepened sufficiently to enable it to carry 2,500 cusecs. By this means the discharge of the canal at the 75th mile could be trebled as it can only discharge 800 cusecs at present without heading up the water enough to endanger the tank above it. Of the 2,500 cusecs thus discharged through the Mittakandala cutting, I estimate that about 900 would be required for the lands under the canal itself with extensions in Cuddapah. Of the remaining 1,600 cusecs, probably about 1,000 would reach the dam or anicut at Somesila. This supply would be continuous from July to November and would be ample for all requirements in the early part of the year. Later on the reservoir would be replenished by the surplus discharges of its own catchment.

10. Should it be considered that this scheme does not utilise a sufficiently large proportion of the waters of the Tungabhadra, it might be possible to take off a much larger quantity by forming a dam across the river and making a tunnel through the high ridge which separates the Tungabhadra basin from that of the Kunderu. This would virtually amount to making a new head to the Kurnool canal and would do away with the 75 miles of dangerous channel which now exists. Two possible sites have been suggested—

(1) Near the village of Nagatur near the 42nd mile of the canal. From this point a tunnel would be taken in a south-easterly direction and the water would be discharged into the Kunderu, somewhere near the village of Parumanchala.

(2) A dam near Sangamesvaram a little below the confluence of the Kistna and Tungabhadra with a cutting and tunnel somewhere near the present cutting near Mittakandala. No surveys have been taken, but the first of these proposals would probably be cheapest as a much smaller body of water would have to be dealt with, the length of the tunnel being about the same in each case. The work would be very expensive involving a tunnel at least 5 or 6 miles long and on further investigation may prove impracticable.

11. Three schemes of varying magnitude may therefore be proposed—

I. The improvement of the Kurnool canal to carry 2,500 cusecs. The construction of an anicut at Somesila and the formation of storage tanks in Nellore.

The cost of this may be roughly estimated as follows :—

	LAKHS.
Improvements to Kurnool canal above 54th mile	0·75
Contour channel from 54th to 61st mile	[illegible]
Deepening and widening from 61st to 75th mile	[illegible]
Anicut and storage works in Nellore	40·00
Total ...	46·00

The returns to be expected would be—

Increase of cultivation in Cuddapah, 20,000 acres at Rs. 5	1·00
" in Nellore, 40,000 acres at Rs. 5	2·00
Total ...	3·00

This would give a return of 6½ per cent.

II. The same improvements to the Kurnool canal, but the construction of a reservoir at Somesila substituted for improvements to the tanks.

The cost of this would be—

	LAKHS.
Improvements to Kurnool canal as above	6·00
Reservoir at Somesila	60·00
Distributaries, etc.	20·00
Total ...	86·00

The returns would be—

20,000 acres in Cuddapah	1·00
100,000 " in Nellore	5·00
Total ...	6·00

or a little higher yield on the capital outlay than the first scheme. It is, however, quite doubtful whether it would be found possible to construct a reservoir at Somesila.

III. The third form would be the same as the second, with the substitution of a new dam and cutting for the improvements to the Kurnool canal. The cost of such a work is very difficult to guess even roughly. It may be put down approximately as follows :—

	LAKHS.
Dam and tunnel to Kunderu	120
Reservoir in Nellore	60
Distributaries	20
Total ...	200

With this combination, the area irrigated would, practically, only be limited by the demand for water. I do not think it likely to exceed 20,000 acres in Cuddapah and 150,000 acres in Nellore. This would give a return of $8\frac{1}{2}$ lakhs or a little over 4 per cent. on the capital outlay.

12. The above approximations are admittedly very unsatisfactory, but they are enough to show that something may be done to improve cultivation south of the Pennér in Nellore district. It is undoubtedly certain that, if water were provided, it would be readily utilised on all classes of soil. The existing tanks, especially those removed from the coast, received a very precarious supply and for some years past ragi has been the principal crop grown under them. On a recent inspection I found that with the influx of a fair supply of water into the tank the ragi, which had already been planted, was in many cases being uprooted to make room for rice. I have not the slightest doubt, therefore, of the water being readily utilised if provided.

13. I have not alluded to the possibility of the combination of the Bellary project with the utilisation of the water further down as this point is, I believe, being taken up by the Chief Engineer for Irrigation.

What is first required is a full investigation of the best means of utilising the water which now goes to waste.

SURPLUS discharges of the Tungabhadra over Sunkesala anicut for the last ten years.

Months.	1891-92.	1892-93.	1893-94.	1894-95.	1895-96.	1896-97.
1	[illegible]	[illegible]	[illegible]	[illegible]	6	7
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.
April	..	..	267	1,082	1,970	..
May	4,267	4,692	8,801	6,936	5,157	..
June	12,084	31,744	39,837	17,139	31,644	..
July	90,853	173,864	72,539	63,455	77,323	3
August	97,217	139,119	82,661	89,263	105,914	3,245
September	35,082	123,879	56,078	29,352	39,413	46,376
October	40,042	52,671	74,631	26,726	50,271	195,726
November	11,205	15,099	15,552	14,725	17,994	326,676
December	810	7,269	4,313	1,181	3,615	49,147
January	..	3,174	..	..	..	39,248
February	..	..	..	..	..	30,354
March	..	3,179	..	..	..	12,015
Total ..	291,560	554,690	354,679	249,859	333,301	702,785

Months.	1897-98.	1898-99.	1899-1900.	1900-1901.	Average.
	8	9	10	11	12
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.
April	507	112	6.640	200	1,078
May	213	6,312	7,590	6,497	5,047
June	88,339	46,440	44,122	27,661	33,901
July	98,993	114,480	98,421	285,394	107,533
August	217,980	148,745	48,776	272,896	120,581
September	169,227	120,930	110,007	99,084	82,944
October	104,738	136,652	34,265	58,451	77,417
November	22,560	66,707	8,661	19,896	51,907
December	10,198	24,186	..	12,093	11,281
January	416	13,304	..	520	5,666
February	..	910	..	11,016	4,228
March	..	..	..	2,028	1,722
Total ..	713,181	678,778	358,482	795,736	503,305

Note on utilisation of Tungabhadra surplus by Colonel A. W. Smart, R.E.

Hitherto the Tungabhadra project has been regarded as a project for irrigation in the Bellary district and has been generally condemned because—

(*a*) The people do not want rice cultivation and will not utilise water for the purpose (instances, Daróji tank and Kurnool-Cuddapah canal). The dry crops which they prefer are cholam, ragi, cumbu and cotton and, under ordinary conditions of rainfall, excellent crops are raised.

(*b*) The engineering difficulties are very great and the cost for overcoming them will be enormous. If the reservoir is located on the Tungabhadra itself, there would be many villages and much land submerged belonging in great part to the Nizam. The bill for compensation would be very great. These are serious objections and they may be accepted as those generally held by all officers whether of the Revenue or Public Works Department.

2. In bad years, however, with a deficient rainfall, the ryots would take the water for saving crops, as instanced by the case of the Kurnool canal, where, in 1876, over 90,000 acres dry were irrigated. The channel taken from Valvapur would command from 500,000 to 600,000 acres of land under dry crop and a reservoir of 30,000 millions cubic feet would be sufficient to irrigate 600,000 acres of such land. The total area cultivated in Bellary in 1900 was 2,150,917 acres. To save one-fourth of this area in a year like 1876 would be an incalculable benefit to the district.

3. The right way, however, is to deal with the surplus of the Tungabhadra as a whole and not piecemeal. If this is done a feasible protective and productive project is possible. The engineering difficulties are great, but they are not insuperable.

Looking at the statements of surplus discharges of the Tungabhadra at the Sunkesala anicut and of the Kistna at Bezwada, we may say that 100,000 millions cubic feet are available for storage from June to October and may be utilised in the districts of Bellary, Anantapur, Cuddapah, Nellore, Kistna and the Nizam's territory. Of this surplus 30,000 millions cubic feet may be reserved for use in the Nizam's Dominions. In the absence of many essential levels and of detailed investigation, it is impossible to more than indicate generally and superficially the possibilities of the case. Of these districts, the only one in which there is any doubt with regard to irrigation is Bellary ; in ordinary years it may be assumed that the water will not be used save to a small extent. On the analogy of the Kurnool canal we may take 30,000 acres as likely to be the maximum of rice cultivation in Bellary ; in years of deficient rainfall 500,000 acres dry crop may be irrigated.

4. There are three ways in which the general project may be worked out—

(*a*) A large storage work on the Tungabhadra at Valvapur, which is the best site yet found on that river. If this is condemned for adequate reasons, then storage must be on one or more of the branches. It will be seen from the surplus statement that a reservoir of 30,000 millions cubic feet on the main river will give at least 50,000 to 60,000 millions cubic feet and will be a much more powerful work than any combination of storage works on the branches. The channel would be taken preferably on Gordon's high level above Bellary to the Huggari ; it would cross that river (on which there should also be a reservoir, if possible) and then branch into two—one branch passing down the right bank of the Huggari towards Adóni and the other across the water-shed into the Pennér. The discharge of the main channel at the head may be taken provisionally at 6,000 cusecs, or may have to be increased because of the large inevitable loss by absorption.

(*b*) The upper part, or Bellary part, may be dealt with separately and the Kurnool canal improved so as to take at least 2,500 cusecs. This is a very poor substitute and is only mentioned as a possible combination. The discharge of the canal should be increased quite independently of these proposals.

(*c*) A reservoir at Valvapur as in the first case and a high dam at Nagatur below Sunkesala or below at junction of Kistna and Tungabhadra, with cut and possibly tunnel into the Kondair, an affluent of the Pennér. In this case the upper channel for Bellary may be designed to take 3,000 cusecs and the Nagatur channel also 3,000 cusecs

5. In Nellore irrigation will be taken up eagerly and will only be limited by the area commanded. In the absence again of levels and of detailed investigation it is impossible to say what area is likely to be irrigated. Storage will be required whether on the main Pennér or in the district itself. A 20,000 million cubic feet reservoir on the Pennér will be filled with Tungabhadra water and with the ordinary supply of the Pennér would be sufficient filling $1\frac{1}{2}$ times for 150,000 acres of rice cultivation ; with good distribution the duty should rise to 200,000 acres of rice. (In the case of the Periyár, a storage of 7,000 millions cubic feet is expected to irrigate 100,000 acres.)

6. The importance of passing an adequate supply of water from the Tungabhadra into the Pennér cannot be exaggerated. It will not only bring a large tract in South Nellore under irrigation, but will steady the supply to the Sangam and Nellore channels and perhaps, most

important of all, it will release the upper waters of the Pennér and branches for utilisation in Anantapur and Cuddapah. There need be no fear then that reservoirs or anicuts on the branches of the Pennér will infringe lower irrigation rights.

7. With regard to the Bellary part of the project, it may be for the present assumed that in five out of six years the water, save for 30,000 acres of rice, will not be utilised. Can it be utilised elsewhere? Undoubtedly it could either on the Kistna or Nellore for second crop. At the end of the irrigation season, when it would be certainly known that Bellary did not require the water, the reservoir could be emptied at the rate of 4,000 cusecs, of which 2,000 cusecs may be assumed will arrive at Bezwada. A portion could no doubt be utilised advantageously by the channels taking off the Tungabhadra above including the Kurnool canal. The 2,000 cusecs arriving at Bezwada would in the three months at the end of the season be sufficient for 200,000 acres of second crop and would yield a revenue of Rs. 6,00,000. (As suggested by Mr. Lacey, in his answers to the Public Works Department questions, it would be well to give water in the Kistna for dry crop only and not for rice.) On the 500,000 acres dry which may be irrigated in Bellary in a bad year, a charge of Rs. 2 an acre may be imposed. (In the case of the Kurnool canal the charge for irrigating dry crop is Re. 1 per acre, but is certainly too low a rate for saving crop already on the ground.) A tax of 4 annas an acre as insurance would be certainly justified for years when water is refused. It is suggested that this tax should give the right to one watering at seed time. It is often the case that deficiency of rain at the beginning of the season delays sowing most prejudicially to agricultural operations. To give water for sowing should act as a great encouragement to the regular use of water throughout the season and the gradual extension of the practice of irrigation. On this point Mr. Wedderburn in 1863 (see his report printed with G.O., No. 2773, dated 24th September 1863) said "with a prospect of water agricultural operations might "commence at an earlier date than they now do, because the first ploughing depends at present "on rain falling in June and July and it often fails."

8. Judging from the figures given by Mr. Clerk and from previous partial investigations, the capital cost of all the works required for storing and utilising the Tungabhadra surplus, including minor reservoirs on the branches of the Pennér for use in the districts of Anantapur and Cuddapah, may be taken at 3 millions sterling.

On the revenue side we have—	RS.
200,000 acres Kistna second crop at Rs. 3 (or say, 150,000 in Kistna and 50,000 in Nellore)	6,00,000
30,000 acres (rice) in Bellary at Rs. 4	1,20,000
500,000 acres Bellary insurance at As. 4	1,25,000
In Cuddapah—	
30,000 acres at Rs. 4	1,20,000
In Anantapur—	
30,000 acres at Rs. 4.	1,20,000
In Nellore *—	
150,000 acres at Rs. 4	6,00,000
	16,85,000
Loss in Kistna in bad year, say, 400,000.	
(It will be noticed from surplus discharges that water may be stored in October so that after supplying Bellary in a bad year up to October there should be some water left for Kistna, so that loss of second-crop water in Kistna would only be partial.)	
Gain in bad year in Bellary 500,000 ~~acres at~~ Rs. 1¾, Rs. 8,75,000.	
This would give yearly (say)	75,000
Total revenue ...	17,60,000
Deduct for maintenance ...	3,00,000
Net revenue ...	14,60,000

or a little over 3 per cent. on capital cost.

(* If more can be commanded more will be irrigated.)

The revenue in Nellore will be greater than shown. There will be some second-crop cultivation and as said before a much larger area may be irrigated if commanded. It may be said then under the best conditions that the project will pay from 3 to 3½ per cent. But should it fail to do so and if the percentage were reduced to 2 or even less, would not the project even then be justified? Colonel Hasted in 1883 speaking of the Kurnool canal (see G.O., No. 184 I., dated 28th February 1883) says "in one respect it (the canal) is of greater value than can readily be estimated, that is, as a famine protective work. In the late famine (of 1876-77) the canal irrigated 90,373 acres, which without water would have been barren waste, and this when its use was not known and appreciated. In future times of scarcity it is certain that the people will avail themselves largely of the canal. It runs through districts which are some of those most liable to famine in this part of India and commands a very large tract of

country, and when in the unprotected parts of these districts people are dying of starvation by hundreds and thousands who can put a money value on the produce of 500 square miles well watered". This is an aspect of the case which it behoves Indian statesmen to consider and it remains for them to say whether the general ideas of Sir Arthur Cotton, modified by our experience, should not, as regards this part of the Presidency, be carried to completion. What is now, however, required is a full detailed investigation.

From W. B. GORDON, Esq., Secretary to the Indian Irrigation Commission, to the Secretary to the Government of India, Revenue and Agriculture Department, dated Nagpur, 9th March 1902, No. 364.

I am directed by the President of the Irrigation Commission to address you on the subject of a survey which the Commission recommend should be at once undertaken to determine the best means of storing the waters of the Tungabhadra, Kistna and Pennér rivers, and of utilizing them for the extension of irrigation in the five districts of the Madras Presidency which are noted in the margin.

1. Bellary.	3. Kurnool.	5. Nellore.
2. Anantapur.	4. Cuddapah.	

2. These five districts—Nellore less than the other or Deccan districts—are more liable to severe visitations of drought than any other part of the Madras Presidency. They were devastated by the famine of 1876—78; and since then they have suffered, some or all and with more or less severity, from deficient rainfall in 1884, 1891, 1896 and 1900, or on an average once in every five years. In 1876—78 the loss of life was appalling; the succeeding census showed a decrease in the population of over 11 per cent. in Nellore, of 17 to 20 per cent. in Bellary, Cuddapah and Anantapur, and of 26 per cent. in Kurnool. The populations of Kurnool and Cuddapah are still less than they were 30 years ago. In only six out of the nineteen taluks comprised in the two districts has the population reached its previous figure; the bulk of the present canal irrigation lies in three of these, while a fourth is fairly protected by wells. The cost of relief operations, with the losses of revenue due to deficient rainfall in these districts during the past 26 years, is reported to amount to over six crores of rupees. In Bellary, Anantapur and Nellore only about 3 per cent. of the cultivated area can now be irrigated in a dry year, and in Kurnool and Cuddapah only 8 to 10 per cent. In view of these significant figures the Commission think it needless to dilate upon the extreme importance of thoroughly investigating every possible means of extending irrigation in this part of the Presidency.

3. All five districts lie within or near to the catchments of two large rivers—the Kistna, with its tributary the Tungabhadra, and the Pennér—whose flood waters if they can be stored and carried on to the land, will afford the means of irrigating a very large area. The proposals which have been made for utilizing these rivers are clearly stated and briefly reviewed in the accompanying note by Mr. Higham. Of Sir Arthur Cotton's proposals for storage works and canals dependent on the Tungabhadra only one portion—the Kurnool-Cuddapah canal—has been carried out. Judged from a purely financial standpoint, that work has been a failure, owing partly to an exaggerated capital expenditure consequent on the arrangements made with the late Madras Irrigation Company, partly to the heavy expenditure incurred for the sake of rendering the canal navigable, and partly to the prevalence of black cotton soil in the tract through which it was aligned. The Commission, however, have no doubt that if effect be given to the proposals referred to in paragraphs 15 to 17 of Mr. Higham's note, the financial position of the canal will be materially improved, while its protective influence will be extended in the districts of Kurnool and Cuddapah and possibly also in Nellore.

4. For the protection of Bellary and Anantapur no works of any importance have yet been carried out. That portion of Sir Arthur Cotton's scheme which is known as the Bellary project has never been constructed. It was conceived solely for the protection of Bellary, and would not have directly benefited any portions of Anantapur, Cuddapah or Nellore. The scheme has been frequently dismissed on the ground that the possible area in which irrigation might be extended in the Bellary district, which consists mainly of black cotton soil, would be too small to justify the enormous expenditure required. It is now proposed (paragraphs 9 and 10 of Mr. Higham's note) to substitute for the Bellary project a more extensive scheme for a canal which will not only irrigate a large area in Bellary, but also render possible a considerable extension of irrigation in the Anantapur, Cuddapah and Nellore districts, in the last of which at any rate the water of the canal would be fully utilized in years of normal rainfall, even though the black soils of Bellary and Anantapur would require but little water. As far as levels are concerned the project appears to be perfectly feasible, though the cost will undoubtedly be high; but if detailed surveys should show that this scheme is not feasible or that its cost is prohibitive, the question of further increasing the capacity of the Kurnool-Cuddapah canal will have to be considered so as to provide, as originally contemplated, for the requirements of Nellore in addition to an extension of irrigation in the Kurnool and Cuddapah districts. In any case the all-important question of storage of the flood waters will require very careful investigation.

5. Mr. Reid's proposal for a large storage work on the Kistna river, and a canal to irrigate the uplands of the Kistna district and that portion of Nellore which will not be commanded by the proposed Tungabhadra canal or by the Kurnool-Cuddapah system, is referred to in paragraphs 18 to 21 of Mr. Higham's note. Kistna and Nellore, especially the former, are less in need of protection than the Deccan districts; but the scheme promises to be remunerative as well as protective, and the Commission consider that the surveys should be completed and the detailed plans and estimates prepared as soon as possible.

6. For none of these projects have complete surveys been made or plans and estimates prepared, and it is obviously impossible for the Commission, at this stage, to form any final opinion regarding them, either from an engineering, protective, or financial standpoint. But after a careful consideration of the plans and proposals as they stand, the Commission are of opinion that no time should be lost in completing the surveys, collecting the information, and preparing the plans and estimates on which final opinion can be formed.

7. With this object I am to recommend that the most competent officers available be employed on the early investigation and preparation of the following projects:—

(i) Remodelling the Kurnool-Cuddapah canal, so that it may carry to the 75th mile as great a supply as can be conveniently carried by that route (from 1,600 to 2,500 cusecs), and constructing the Chepad, Velgodo and other suitable channels for carrying the supply to lands in which wet cultivation will be practised.

(ii) Measures for utilizing the surplus supply that will thus be made available for the Pennér, so far as this can be done without prejudice to the greater scheme for the extension of irrigation in Bellary and Nellore districts, or to the supply now required for the Sangam anicut and Pennér river systems.

(iii) The construction of a canal from the Tungabhadra river—not merely to irrigate parts of the Bellary district, but a much larger work to traverse the Bellary district, to cross the Huggari river, and to pass into the basin of the Pennér, water sufficient to protect large areas in the Anantapur, Cuddapah and Nellore districts. The taluks of Pulivendla and Kadiri in the Cuddapah district are specially in need of protection, and the possibility of carrying a branch into these taluks across the upper basin of the Pennér should be investigated. In Bellary there will be but a small demand for water in ordinary years, while in years of drought it will be necessary to extend protection to the largest possible area of dry-crop cultivation in that district; and the canal must be designed to meet these varying conditions. The extra supply required for Bellary in dry years will be obtained by restricting the supply passed into the Tungabhadra or Pennér for second-crop cultivation in the districts below.

(iv) Storage works on the Tungabhadra and its tributaries, whether in the Bellary or Dharwar districts or in the Hyderabad or Mysore States; and on the Pennér and any other rivers to which water can be supplied by means of the proposed canal.

(v) Storage works and a canal from the Kistna for the irrigation of the Kistna and Nellore districts.

8. In the event of its being found impossible to secure adequate storage for project (iii), or to carry a canal of the required dimensions through the Bellary district except at a cost which will be prohibitive, the question should be considered of carrying the whole supply required for Nellore along the Kurnool-Cuddapah canal route, and the following alternatives should be investigated:—

(1) The complete reconstruction of the first 75 miles of the Kurnool-Cuddapah canal.

(2) The construction of a canal on the left bank of the Tungabhadra, to take off above the Sunkesala anicut and to be carried across the Tungabhadra lower down by means of an aqueduct. A very slight examination of the country should suffice to show whether this alternative deserves closer investigation.

(3) A dam across the Tungabhadra lower down with a cut or tunnel into the head of the Kundaur nullah.

This scheme will also comprise the construction of suitable storage works on the Tungabhadra and Pennér, but these will of course be on a smaller aggregate scale than required for the larger project, as the Bellary, Anantapur and Cuddapah districts will be cut out of the scheme.

9. In determining the best sites for storage reservoirs and generally in carrying out these schemes, it will be necessary to secure the assistance and friendly co-operation of His Highness the Nizam and of His Highness the Maharaja of Mysore. I am therefore to suggest that, at the proper time, their Highnesses should be invited to permit the prosecution of the necessary surveys within their respective territories and to give such assistance as may be in their power; and that the officers entrusted with the investigation should be instructed to give due consideration to the probable requirements of these States as far as irrigation from the proposed works is concerned, and to consider the advisability of offering to them a fair and reasonable share of the benefits to be derived from the storage of flood waters within their territories.

10. In conclusion I am to observe that every alternative put forward in connection with the Tungabhadra project involves great difficulty and great risks, and it is hardly possible to suppose that any scheme can be formulated which will prove directly remunerative. It is on this account that previous preliminary enquiries have not been completed and that the results have been pigeon-holed on the strength of *a priori* arguments that no scheme can possibly prove remunerative. The failure of the Kurnool-Cuddapah canal has had a most unfortunate effect in discouraging other proposals for the extension of irrigation in the Deccan districts. But the protective value of that canal, even in its present condition, is now generally recognized, and many think that the cost of its construction has been justified. Many lessons have been learned from its failure to do all that was anticipated, and many of the mistakes which have been made will not be repeated in future. It is now possible to form a more reliable estimate of the protective and financial results of any new work that may be proposed, and it is realized that Government will not reject valuable protective schemes merely because they do not satisfy the technical definition of a productive public work, but will be prepared to accept a certain excess of interest charges over net revenue in consideration of the value of the protection that will be afforded. The Tungabhadra project therefore should not be finally dismissed until all possible alternatives have been thoroughly and exhaustively investigated and accurate estimates have been prepared of the areas which it may be relied on to protect, and of the permanent charges on the State which will result from its construction. It will then be for Government to decide whether the work should be undertaken. All that the Commission can now say is that no such estimates are at present available, and that an early and thorough investigation is earnestly recommended.

Note on the Tungabhadra and Kistna Projects by T. Higham Esq., C.I.E., dated 18th March 1902.

The four parts of the Tungabhadra project.

1. The complete Tungabhadra project as originally conceived by Sir Arthur Cotton may be divided into four parts, thus—

(1) Storage reservoirs on the Tungabhadra or its tributaries.

(2) Bellary project, for a canal to take off from the Tungabhadra somewhere above Hospet for the irrigation of Bellary district only, eventually tailing into the Kurnool-Cuddapah canal somewhere near Kurnool.

(3) Kurnool-Cuddapah project, for a canal to take off from the Tungabhadra above Kurnool to carry a supply sufficient for the irrigation of portions of the Kurnool and Cuddapah districts, and an additional supply to be discharged into the Pennér river for utilization in Nellore district. This has been constructed.

(4) The Nellore works, for the utilization of the waters of the Pennér when supplemented by the Tungabhadra water to be brought down by the Kurnool-Cuddapah canal.

Reasons for first constructing part (3).

2. On Sir Arthur Cotton's recommendation, part (3) was first put in hand and is the only part that has been executed. It is easy to understand why a commencement was made with this part. No storage works were really required in order to supply this canal with the water required for the irrigation of a first-crop only in the Kurnool and Cuddapah districts. It was no doubt thought that this part could be completed and broght into operation while parts (1), (2) and (4) were under discussion and this has indeed proved to be the case. The completion of the three parts would not very materially improve the position of the Kurnool-Cuddapah canal. It has sometimes been said that this canal is but the middle link of a system and that its failure is sufficiently accounted for by the fact that the head and tail of the system have never been constructed, but this is not the case, and Sir Arthur Cotton himself originally declared that this middle link when completed would yield its own returns independently of the other parts. The reasons why it has not done this will be considered presently.

The irrigation of Nellore depended on part (3) and not on part (2).

3. The next point to be noted is that the irrigation of the Nellore district depended on the completion of the Kurnool-Cuddapah canal, or part (3) of the system. General Fischer has told us in his evidence that Sir Arthur Cotton originally proposed to irrigate Nellore by an extension of part (2) or the Bellary project, and that the idea was abandoned, not because it was absolutely impracticable, but because General Fischer had succeeded in convincing Sir Arthur Cotton that water could be more easily taken into Nellore by the Kurnool-Cuddapah route, and that it was waste of time to consider the question of the Bellary route, which has now been independently revived by the Chief Engineer, Madras Irrigation Works.

Part of the full supply, for which part (3) was designed, was intended for Nellore.

4. Be this as it may, it is certain that the Madras Irrigation Company proposed to adopt the Kurnool-Cuddapah route for the conveyance of Tungabhadra water into Nellore, and always regarded the Bellary project as intended only for the irrigation of the Ballary district. The Kurnool-Cuddapah canal was therefore designed

with a capacity at the head of 3,000 cusecs. It is not clear how much of this supply was to be assigned to the Kurnool-Cuddapah districts, and how much to Nellore. It is certain that it was never proposed that Kurnool and Cuddapah districts should take between them the whole 3,000 cusecs, but the requirements of Nellore appear to have been under-estimated if it were thought that the balance would suffice for this district. It is probable that the engineers of those days overestimated the natural supply of the Pennér river, or proposed large storage basins upon it and its tributaries. It was certainly not contemplated to pass down a supplementary supply by means of the Bellary project, and it was always proposed to feed the Pennér by the Kurnool-Cuddapah route alone. It may be here remarked that it was not necessary to carry this additional supply through the entire length (200 miles) of the Kurnool-Cuddapah canal. The full supply had only to be carried to the 75th mile, or head of the Kundaur valley, from which point any required supply can be passed down the natural drainage line, the lower 125 miles of the canal being required merely for carrying the local supplies, and for purposes of navigation.

Kurnool-Cuddapah canal cannot carry more than 800 cusecs.

5. As a matter of fact, however, the canal has never been capable of carrying anything like 3,000 cusecs. We have it in evidence that the maximum supply that has been passed *through the head reaches* is only 2,000 cusecs and that not more than 1,800 cusecs could be contemplated as ordinary full supply. Five years ago the maximum was said to be 1,200 cusecs. These are the discharges in the head reaches for purpose of filling the lakes. Below the lakes the capacity is much less, and it is said to be impossible even now to pass more than 800 cusecs into the cutting below the Tangadentza tank or the 61st mile without endangering the safety of the tank. As the canal at present stands, it is impossible therefore to pass any considerable and regular supply into the Nellore district.

Estimated requirements of Nellore district, and possibility of increasing capacity of Kurnool-Cuddapah canal to meet them.

6. It is now estimated that a supply of 3,000 cusecs is the least required for the Nellore district. Allowing for present and future requirements of Kurnool and Cuddapah districts, where there is room for some extensions of irrigation, a supply of something like 4,500 cusecs would be required at the head of the canal in order to pass 3,000 cusecs into Nellore. The question is whether the first 75 miles of the present canal can be so remodelled as to pass this extra supply. It is said that the cost would be prohibitive. I do not think that it can be said without further investigation that the cost will be greater than that of other alternatives which have been proposed, but it is doubtful whether such a remodelling could be carried out even at a high cost without interrupting the present supply for at least two seasons, and this at any rate is a very serious objection.

Alternative of a dam near junction of Tungabhadra and Kistna.

7. The first alternative proposed is to construct a high dam across the Tungabhadra immediately above or below its junction with the Kistna, and to take whatever may be required for the Nellore supply in addition to the quantity that can be passed down the present channel by means of a new canal taking off 50 or 60 above the bed of the river and discharging into the head of Kundaur valley. The dam and channel (which would be in very deep rock cutting) would be very costly, but could be carried out without seriously interrupting the supply to the existing canal.

Alternative of a left bank canal and aqueduct.

8. General Fischer has suggested a second alternative, viz., that the new canal should take off from the left bank of the river opposite the present head of the Kurnool-Cuddapah canal and be carried down that side until it can be taken across the river into the Kundaur valley by means of an aqueduct. Until the other side of the river has been examined, it is impossible to say whether this suggestion is worth serious consideration, but it is an alternative to be borne in mind. Even if the country is favourable, the fact that the canal will have to be carried for several miles through the Nizam's territory is in itself a serious objection.

Fourth alternative offered by the Bellary project.

9. There are thus three alternatives for carrying water into Nellore through the Kurnool and Cuddapah districts, neither of which can be regarded as promising, though each may deserve consideration. The fourth proposal is to give up this route altogether and to carry the required supply into Nellore by means of a great canal traversing the Bellary district, as at one time contemplated by Sir Arthur Cotton. The Bellary project has hitherto been worked out on the assumption that it is only necessary to provide for the irrigation of the Bellary district, and it has been considered that it would be useless to provide for a greater area than 50,000 acres wet crop in this district. It has not been difficult to show that the heavy expenditure which would be involved in carrying a canal through the Darója hills could not be justified for the sake of irrigating so small an area, but if water can also be carried into Nellore by this route, the project may be less unpromising.

Advantages of supplying Nellore by means of the Bellary project.

10. If this project is feasible, it will have many advantages as compared with a scheme for passing the same supply through the Kurnool and Cuddapah districts. It will traverse the Bellary district and afford it all the protection proposed in the original Bellary project, which must be regarded as very unpromising if its scope is restricted to the irrigation of a corner of the Bellary district. Under this scheme it will not, moreover, be necessary to force wet cultivation on the occupiers of black soil in the Bellary district. The water can be utilized for dry-crop irrigation in a year of drought and so afford invaluable protection to this district; but if not taken in ordinary years it can be passed on and stored in the Nellore district when it can be made available for a second crop. In dry years water will not be available for a second crop in the latter district; but it will be sufficiently protected if it has a single crop. Lastly, the supply will enter the Pennér river much higher up than if carried down the Kundaur valley and it will be possible to make considerable extensions of irrigation from the Pennér in the Anantapur and Cuddapah districts.

Feasibility of the Bellary project.

11. As far as levels are concerned the projects appears to be perfectly feasible and if good sites for dams can be found it seems probable that large storage reservoirs may be formed below the points at which the proposed canal would enter the Huggari and Pennér rivers. The question is, however, one of cost. Colonel Baddeley considers that the cost of carrying a channel through the Darója hills would be prohibitive if the sole object were the irrigation of 50,000 acres of wet crops in the black soil of the Bellary district; but this objection will not necessarily apply to a larger scheme on the scale now proposed. It is at any rate not obvious that this project will be more costly, in proportion to the area which will be brought under protection than either of the three alternatives for carrying a supply into the Pennér by the line of the Kundaur valley, which have already been discussed. Colonel Baddeley's estimates are based on Mr. Gordon's survey of 1866. Mr. Gordon's alignment was accepted after close and careful examination by one of the most competent of the Madras Irrigation officers (Captain Mullins, R.E.), and it was probably the best possible line for what was then proposed—a channel with a capacity of 2,250 cusecs starting from a certain level at Valvapur which was to command the station of Bellary, and not to be carried beyond the Bellary district. It is not now considered obligatory to command the station of Bellary, and with new data a more favourable alignment might be found. It may, for instance, be possible to take off from a Valvapur reservoir at a level 40 or 50 feet higher than that originally proposed. This would somewhat reduce the storage available for the Bellary project; but if good sites for storage works could be found on the Huggari and Pennér this would not be a matter of much importance, and the balance in the Valavapur reservoir could all be utilized for second crop on the Kurnool-Cuddapah and Kistna canals. Other possibilities may be suggested, and in view of the great advantages which this scheme presents as compared with the alternatives which have been proposed, I do not think that it should be dismissed until it has been thoroughly examined by the most competent officer who can be found. It should be realized that a feasible *alignment through the Darója hills is the key* of the problem of providing adequate protection for Nellore and the four Ceded districts.

Storage reservoirs.

12. We now come to point (i) of the original project, or the important question of storage reservoirs without which any considerable extensions of irrigation in the Bellary and Nellore districts are out of the question. The sites which have been proposed are—

(i) General Fischer's site near Hospet.
(ii) The Valvapur site, nine miles higher up the river.
(iii) Various sites on the tributaries in Mysore territory.

(i) would probably be the best site if the Bellary project be abandoned and either of the other alternatives for carrying a supply into Nellore be adopted. It is, however, 60 feet lower than the Valvapur, and this will involve a great loss of command for any Bellary project. I am not sure that this consideration is conclusive against the adoption of this site, as it may be found advisable to sacrifice a certain amount of command for the sake of other advantages, a point which can only be determined by comparative investigation. *Primá facie* it would appear, however, that a Bellary canal cannot take-off lower down the river than Valvapur, and it may even be advisable to go still further up the river. It does not necessarily follow that the resevoir should be placed at the site of the take-off. If sufficient storage can be found on suitable sites higher up the main river or on its tributaries, or lower down *in the drainage lines that will be* crossed by the Bellary canal, such as the Huggari or Pennér, a simple anicut would suffice for the take-off, but undoubtedly the most effective site for a reservoir would be one on the main river. Any storage work on the main Tungabhadra or its tributaries will however involve the submergence of large areas of foreign territory, either in Hyderabad or Mysore, or in both, and very high claims for compensation, even if other objections on the part of the States can be removed. This is a difficulty that must be faced, but a complete survey of all possible sites, and a careful estimate of the storage really required, will have to be made before any definite proposals to the States can be formulated. One point to be considered is that, unless special arrangements are made, Hyderabad may be able to appropriate a large share of the supplies that may be passed down the Tungabhadra from storage works. This is in itself a very strong argument for the Bellary project as now put forward. It must be remembered, however, that an arrangement by which we can enable the Nizam's Government a share in the benefits to be derived from storage reservoirs is in itself desirable, if it will secure the co-operation instead of provoking the opposition of the Darbar, and will increase the area under protection in Hyderabad territory, a matter of great importance. It is understood that the Madras Government now feel it their duty to object to any extension of irrigation in Hyderabad which may involve the slightest diminution in the cold-weather supply of the Tungabhadra or Kistna. The construction of ample storage works on the Tungabhadra and elsewhere, in such a way as may secure the hearty co-operation of the Nizam's Government, appears to be the only means of relieving them from this invidious position. A principal object of our enquiries when we go to Hyderabad should be to ascertain the limit of possible extensions of irrigation in the Nizam's territory from these two rivers, which should be considered in any proposals for storage works that may be brought forward.

Colonel Smart's figures for the Tungabhadra project.

13. All the schemes for the extension of irrigation in Bellary and Nellore districts which have been noticed above are at present of so nebulous a character that no approximate idea can be formed of either their cost or probable financial and protective results. We can only consider the figures given in Colonel Smart's as the most favourable that can be hazarded, and judge whether they are good enough to justify further investigation. Colonel Smart puts the cost of a great canal in Bellary, and of complementary irrigation works in the Cuddapah, Anantapur and Nellore districts, at Rs. 4½ crores. This includes all necessary storage works on the Tungabhadra and elsewhere, but not the cost of improvements on the Kurnool-Cuddapah canal, which is a separate matter, to which I shall presently refer. It is estimated that for this expenditure we shall be able to protect in a year of drought—

	30,000	acres of rice in Bellary.
	500,000	„ of dry crops in Bellary.
	30,000	„ of rice in Cuddapah.
	30,000	„ of rice in Anantapur.
	150,000	„ of rice in Nellore.
	133,000	„ of second crop in Kistna and in Nellore.
Total ...	873,000	

In ordinary years the 500,000 acres dry crop in Bellary would be replaced by 2[illegible]7,000 acres of second crop in the Kistna canals and in Nellore, and the total becomes 640,000 acres for ordinary years.

14. * * * * *

Case of the Kurnool-Cuddapah canal.

15. I now return to the case of the Kurnool-Cuddapah canal, which may be considered by itself, apart from the Bellary-Nellore project. It is usual to ascribe the unsatisfactory results attained on this canal to the unwillingness of the ryots to exchange dry for wet cultivation. I think, however, that if measures had been taken years ago to extend irrigation to tracts in which wet cultivation would have been more readily resorted to, and to utilize all surplus by passing it through the Pennér into storage works in Nellore, the results would have been more satisfactory. There is no doubt that, as General Fischer says, the canal has been wrongly aligned, and that the main line should have been taken along the line now proposed for the Velgode distributary. I should like to see this channel constructed and extended as far as possible, and other extensions might also be carried out in Cuddapah district. We are warned, however, that in dry years the wet lands thus brought under cultivation will get no water as it will all be required for the dry crops. Some control can at any rate be exercised over the distribution, but the argument is an admission that the canal has an insufficient capacity, and is liable to fail when most wanted. So far as the requirements of Kurnool and Cuddapah only are concerned, this might, to a great extent, be remedied by remodelling the waste weirs as proposed by Colonel Baddeley. Mr. Clerk, however, states in his note on the Tungabhadra project that for an expenditure of Rs. 6,00,000 the canal might be improved so as to carry 2,500 cusecs. Colonel Smart doubts whether it can be made to carry more than 1,600 cusecs, but it must be remembered that the present maximum supply below the 7[illegible]th mile is not more than 800 cusecs, and it is therefore a question of doubling or trebling this supply. The canal should be made to carry as much as possible, as any excess over Kurnool and Cuddapah requirements will pass on into the Pennér. The construction of the Somesila anicut or reservoir and of the dependent channels may be afterwards considered, but this will form part of the general Tungabhadra project. Even if these works be not constructed at once, the additional supplies passed into the Pennér by a remodelled Kurnool-Cuddapah canal will be valuable in steadying the supply to the existing Sangam anicut and Pennér river works, which is now somewhat precarious.

Improvement of this canal has been prevented by existing financial rules.

16. I venture to think (judging after the event) that it would have been better policy to have spent 10 or 15 lakhs some years ago in improving the canal and in making extensions into tracts more suitable for wet cultivation than to have employed as special officer in offering special encouragement to the ryots to convert their dry into wet cultivation. The real obstacle in the way was probably the rule that in the case of so-called productive works which had proved unremunerative, any additional capital expenditure must be met from revenue and not from loan funds. In the case of Madras this means that the expenditure must be met from Provincial funds which would not, however, derive any benefit from the expenditure. No better object-lesson than the Kurnool-Cuddapah canal could be given in illustration of the necessity for relaxing the present rule regarding sanction against loan funds, but this is a matter to be dealt with separately.

17. *

Mr. Reid's Kistna project.

18. Since the foregoing note was written in January last, I have seen Mr. Reid's report on his reconnaissance for a storage work on the Kistna, and although such a work would be quite independent of the Tungabhadra scheme, it will be convenient to consider it at the same time. Briefly, it may be said that Mr. Reid proposes to construct a dam across the Kistna at a site 90 miles above Bezwada which shall be 184 feet in height above the bed of the river. A left bank canal will take off at this level, with bed 50 feet below the top of dam, or 134 feet above the bed of the river, the proposed depth of full supply being 10 feet. This canal will, therefore, not run a full supply until the reservoir has filled to a level of 40 feet below top of dam. It is anticipated that in the most unfavourable year this level will be attained by the 15th July, and that it will be maintained until the 15th October, or that the proposed high-level canal would run continuously for at least four months. This canal would traverse the uplands of the Kistna district and might be continued through the northern talukas of Nellore district so as to tail into the Pennér. Such a canal would have a great protective value, as it would protect almost absolutely a portion of the Nellore district which will fall outside of the Tungabhadra or Kurnool-Cuddapah canal extension schemes; but it could never be contemplated to construct a reservoir of this magnitude (it will impound 80,000 million cubic feet) for the mere sake of working this high-level canal for four or five months in the year. It is, however, proposed to utilize the balance of the immense volume that will be stored below the bed level of the upland canal for the extension of irrigation and of second crop cultivation in the delta; or below the Bezwada anicut. It is estimated that the area of single crop in the delta may be increased by 300,000 acres, or from 700,000 to 1,000,000, and that 200,000 acres of second crop may also be relied on, and it is the profits that will result from this new irrigation in the delta that will render the scheme as a whole remunerative. The Kistna delta is already so well protected that the construction of a reservoir for the extension of single or second crop cultivation within it cannot be regarded as a matter of great urgency from a protective point of view; but if, as is anticipated, the project will prove directly remunerative even when weighted with the cost of a work of such great protective value as the high-level canal, the scheme appears to deserve very early and favourable consideration. Mr. Reid has roughly estimated the whole cost of the project at 2½ crores, and the increase of gross revenue at 38 lakhs. Allowing 8 lakhs for working expenses, this would leave an ultimate return of 12 per cent. on the total capital outlay. These figures must, of course, be taken for what they are worth, as a mere rough estimate based upon a preliminary reconnaissance, which shows that there is *primâ facie* good reason to believe that the scheme is feasible, and is likely to prove financially remunerative as well as of great protective value; as apart from the protection which it will afford to the tracts to be traversed by the high-level canal, it will increase the area of food-crops in the delta by something like half a million acres. The report has not yet been examined or criticised by the Chief Engineer for Irrigation, or by the Revenue officers, and the Commission can only consider it at present as a magnificent scheme which is deserving of closer and more detailed investigation.

Probable effect on the Kistna delta and Hyderabad.

19. Another important point which may be urged in recommendation of the scheme is that it will render the Kistna delta entirely independent of the cold and hot weather supply in the Tungabhadra, which may be reserved entirely for the Tungabhadra and Kurnool-Cuddapah projects, and for use in the Nizam's territories. It will be possible to utilize whatever water may be available in the Tungabhadra to the best advantage, without reference to the exigencies of the Kistna delta. There does not appear to be very great room for the extension of irrigation in Hyderabad from either the Tungabhadra or the Kistna; but it is desirable that no objections should be raised to such extensions as may be feasible, on the ground that they will prejudice the supply to the delta, and a reservoir in the Kistna will render it possible to waive such objections. The Chief Engineer for Irrigation, Hyderabad, has informed us that a project is now under investigation for a storage work on the Kistna, near the Bombay-Hyderabad boundary, which will render possible a large extension of irrigation in the doab formed by the Kistna and Bhima rivers. It is possible that the Government of Madras may be compelled to object to such a scheme as likely to prejudice the delta irrigation, but the construction of a second storage work on the Kistna at the site now proposed by Mr. Reid will enable them to waive such an objection. It is also possible that a left bank high-level canal might be made from the proposed reservoir which would command a considerable area in the Warangal taluka of Hyderabad, though it is doubtful whether the land is suitable for irrigation. We have not been able to obtain a clear and reliable opinion on this point while in Hyderabad, and an examination of the country will be necessary. As a matter of principle, I think that the Nizam's Government should be allowed to participate in whatever benefits can be secured by the construction of storage works on either the Tungabhadra or the Kistna if they are willing to pay a reasonable share of the cost. It may be added that the proposed Kistna reservoir will submerge a large area in Hyderabad territory.

Possible objections to the scheme.

20. From an engineering point of view the principal objections to the project are the great height of the dam, and the possibility of a serious interception of silt in the proposed reservoir. The former is not serious if a further detailed examination of the site shows that thoroughly reliable foundations may be relied on throughout. The silt difficulty has, I think, been under-estimated by Mr. Reid, and as in the case of the proposed Cauvery reservoir, careful

and well-devised observations are necessary in order to obtain some measure of the consequences that may be anticipated. In one respect the conditions will be more unfavourable than on the Cauvery, as it will not be possible to empty the reservoir during the flood season without cutting off the supply to the high-level canal. The reservoir will therefore have to be kept full for at least four months continuously. The powerful low-level undersluices proposed will no doubt tend to mitigate the difficulty, but it is nevertheless a real one, and will require very careful consideration.

TUNGABHADRA PROJECT.

Preliminary Report.

The foregoing papers attached to this report should be read first :—

(1) Mr. Clerk's note for the Irrigation Commission ;
(2) Colonel Smart's note for the Irrigation Commission ;
(3) Sir Thomas Higham's note for the Irrigation Commission.

2. *Scope of this report.*—These papers having been read in their order, it will be seen that the project of leading the Tungabhadra into the Pennér and irrigating a large area depends, so far, upon a study of the map and a few disjointed levels. The first thing to do therefore is to ascertain whether the project is really feasible, and by means of skeleton surveys to arrive at a rough notion of the cost and of the area that will be commanded. It will then be possible to estimate what expenditure will be necessary in order to make (what the Irrigation Commission recommends) accurate estimates. A very brief account of what has been done and what remains to be done is here accordingly set forth.

3. *Disabilities of reservoirs on upper waters of Tungabhadra and tributaries.*—The formation of reservoirs on the upper waters of the Tungabhadra or its tributaries has been long since considered as a possibility. Such reservoirs have inherent disabilities. Some have been already alluded to in Mr. Clerk's note. Others are, lack of storage capacity, and lack of power owing to small catchment. These are so grave that they render the idea of such reservoirs *a pis aller* at the best. They need not be further discussed unless it is proved that transformation of the Tungabhadra lower down is impracticable.

4. *Possible reservoirs on lower Tungabhadra.*—Turning then to the course of the river in the Bellary district, it is evident that there are four ways of diverting the Tungabhadra *viâ* the town of Bellary into the Hagari, which is the first step in the scheme :

I. A dam three miles above Hospet and a cutting and tunnel through the Papinayakanhalli pass.

II. A dam at the same place and a canal *viâ* Nelapur, Uparhalli, and Daroji.

III. A dam at Valabhapur, about 10 miles further up the river, and a canal following the same course as in I or II.

IV. A dam lower down the river near Humpi and a canal *viâ* Nelapur.

5. *Elimination of the less favourables.*—Scheme No. IV entails at the outset the submersion of the celebrated ruins of Humpi and of the town of Hospet, and of several miles of railway on both sides of the river. Further, the river-bed in the vicinity of Humpi falls from M.S.L. + 1,400 to + 1,300, and as the Nelapur saddle is + 1,644 an enormously high dam would be needful. This scheme can therefore be left aside.

Scheme No. III involves a longer canal by 10 or 11 miles than either No. I or No. II Further, the site for a dam is by no means a good one. The foundations on the left bank are extremely unpromising and even a low dam would be very long. This alternative may therefore also be left aside.

As regards scheme No. I reference is invited to the accompanying sections of the Papinayakanhalli route. From these it will be seen that with—

Height of offtake above river-bed.	Length of tunnel required.	
Feet.	Miles.	Feet.
100 ...	9	4,280
110 ...	8	4,060
120 ...	8	2,650
130 ...	7	4,640
140 ...	7	1,940
150 ...	7	...
160 ...	6	3,320

This tunnel would have a fall of only 2 feet per mile, which would give a velocity of 4 feet per second and a section of 1,500 square feet for 6,000 cusecs. It would be quite prohibitively expensive, and this route may be dismissed.

6. *Choice admits of no doubt.*—Scheme No. II remains and this, though also expensive, is perfectly feasible. The site for a dam is *primâ facie* a good one, and if the foundations are hereafter proved good, it must be considered excellent. The dam need not be excessively high and will yet give good command and very large storage, while a perfectly practicable line for the main canal has been laid out as far as Daróji. The only serious drawback that at once presents itself is that half the land submerged is Hyderabad territory. This drawback is however shared by the other sites. This scheme may be therefore accepted as that which will be adopted and will be described in a little more detail.

7. *General features.*—There will be a dam at Malapuram, 3 miles above Hospet. From this a canal will take off running *viâ* Nelapur and Uparhalli, thence by a tunnel to the foreshore of Daróji tank. From thence the canal will run *viâ* Bellary to the Hagari, will cross the Hagari, pierce the Hagari-Pennér watershed, and so drop into the Pennér, along the course of which the water will run to the Bay of Bengal. The water will be able to protect or irrigate a great part of Bellary, a part of Kurnool, a corner of Anantapur, large tracts in Cuddapah, and a very considerable area in Nellore.

The Dam and Reservoir.

8. *Description in greater detail—Dam and reservoir near Hospet.*—The dam will hold up about 130 feet of water. The following table gives roughly the areas submerged and the storage at different levels :—

Storage and submersion.

Contour above M.S.L.	Depth above bed.	Area.	Contents.	Difference.
FEET.	FEET.	SQ. MILES.	MILLS. C. FT.	MILLS. C. FT.
1,600	100	77	71,000	..
1,610	110	92	95,000	23,000
1,620	120	111	123,000	29,000
1,630	130	130	157,000	33,000
1,640	140	163	198,000	41,000

9. *Water available.*—The following table gives the surplus at Sunkasala anicut, near Kurnool, for a series of years, month by month :—

Months.	1891–92.	1892–93.	1893–94.	1894–95.	1895–96.	1896–97.
1	2	3	4	5	6	7
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.
April	..	..	267	1,082	1,970	..
May	4,267	4,692	8,801	6,936	5,167	..
June	12,084	31,744	39,837	17,139	31,644	..
July	90,853	173,864	72,539	63,455	77,323	3
August	97,217	139,119	82,661	89,263	105,914	3,243
September	35,082	123,879	56,078	29,352	39,413	46,376
October	40,042	52,671	74,631	26,726	50,271	195,726
November	11,205	15,099	15,552	14,725	17,994	326,676
December	810	7,269	4,313	1,181	3,615	49,147
January	..	3,174	..	..	..	39,243
February	..	..	..	..	..	30,354
March	..	3,179	..	..	..	12,015
Total ..	291,560	554,690	354,679	249,859	333,301	702,783

Months.	1897–98.	1898–99.	1899–1900.	1900–1901.	Average.
	8	9	10	11	12
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.
April	507	112	6,640	200	1,078
May	213	6,312	7,590	6,497	5,017
June	88,339	46,440	44,122	27,651	33,901
July	98,993	114,480	98,421	285,394	107,533
August	217,980	148,745	48,776	272,896	120,581
September	169,237	120,930	110,007	99,084	82,944
October	104,738	136,652	84,265	58,451	77,417
November	29,560	66,707	8,661	19,896	51,907
December	10,198	24,186	..	12,093	11,281
January	416	13,304	..	520	5,668
February	..	910	..	11,016	4,228
March	..	..	..	2,028	1,722
Total ..	713,181	678,778	358,482	795,736	503,305

The following table gives the surplus of the Kistna at Bezwada anicut for a series of years, month by month :—

Months.	1890-91.	1891-92.	1892-93.	1893-94.	1894-95.	1895-96.
1	2	3	4	5	6	7
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.
April	3,353	8,028	7,265	14,312	8,885	7,313
May	16,172	5,451	4,417	11,161	11,027	9,893
June	108,201	23,458	260,659	677,048	160,310	10,153
July	1,317,084	497,454	1,153,057	717,104	1,388,849	507,568
August	1,491,193	1,251,962	997,190	1,087,095	697,008	827,074
September	394,390	404,946	1,660,181	833,699	504,800	776,439
October	217,773	295,087	747,185	737,318	262,518	416,014
November	118,034	15,166	643,985	124,146	167,254	109,188
December	20,896	..	42,404	21,748	22,760	18,090
January	..	..	185,310	..	1,049	2,282
February	..	..	123,425	..	567	1,245
March	7,907	6,356	70,929	..	2,011	6,163
Total ..	3,685,704	2,507,908	5,896,007	4,223,631	3,227,038	2,690,419

Months.	1896-97.	1897-98.	1898-99.	1899-1900.	Average.
	8	9	10	11	12
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.
April	2,617	..	13	9,507	6,129
May	430	2,317	8,389	12,905	8,216
June	203,202	161,235	175,909	89,370	186,026
July	644,676	462,838	541,259	245,679	747,557
August	1,291,895	890,833	567,697	102,553	920,450
September	120,641	488,659	436,213	292,722	591,369
October	43,181	439,643	333,480	16,622	350,882
November	16,008	28,051	69,465	117	129,141
December	21,423	..	11,772	..	15,909
January	..	..	1,205	..	18,985
February	..	..	..	..	12,524
March	512	512	595	..	9,498
Total ..	2,344,585	2,474,088	2,147,997	769,475	2,996,685

From these tables it will be seen that, supposing the worst known year at Bezwada and the worst known year at Sunkesala coincided, it would still be possible to abstract about 225,000 millions of cubic feet without taking any water that does not at present flow to waste in the sea. It will also be seen that there will still be ample water for any reservoir that may be constructed on the Kistna above Bezwada and below the junction of the Tungabhadra.

10. *Offtake level.*—In the preliminary survey it was assumed that the offtake of the canal would be at + 1,610 for full supply level, and the longitudinal section of the canal has been roughly graded on this assumption. This, however, entails a reservoir of rather unmanageable dimensions, and it will almost certainly be found best to take off the canal with full supply level at + 1,600. This reservoir will hold a little more than 70,000 millions below offtake level, for which or for part of which a use may be found either for second crop in the Kistna delta, or for passing through the Kurnool-Cuddapah canal into the Pennér. Supposing the reservoir run dry during the hot weather, the tables show that it will fill to offtake level (+ 1,600) always before the end of July except in one year. This is an important matter, as it allows of fixing within a few days a date for the commencement of supply to the ryots.

Storage below offtake level.

11. *Required storage above offtake level.*—The quantity of water required to be stored cannot be determined without a great deal more investigation on the agricultural side. It is necessary, however, to form a rough working hypothesis. Assuming then that 6,000 cusecs is required for six months, then 3,000 cusecs for three months, the total above offtake level amounts to about 118,000 millions cubic feet. This would raise the water to about + 1,638, and an extra 8 feet for evaporation would raise full supply to about + 1,646. But during several months the supply can easily be kept up to + 1,630, though evaporation and offtake are both going on; and if the reservoir is left at + 1,630 in October with no incomings, there will be enough to supply both offtake and evaporation for the rest of the season. It may therefore be taken that about + 1,630 will be full supply level in the reservoir.

F.S.L. in reservoir.

12. *Floods and their disposal.*—The maximum flood discharge of the Tungabhadra may be taken here roughly at 600,000 cusecs. Preparations must of course be made for disposing of the whole of this. There is little or no possibility of any high level escape, and it may be accepted

that the water must go either over or through the dam. It will probably be found best to discharge it by Stoney's sluices, the lowest of which will be at a level of about + 1,550, but the question is obviously one that needs very careful thought. There will be one or two very low-level sluices for defence against silt and to discharge the storage below offtake level. This, the silt question, will not be as formidable as in other places, but will of course need thorough investigation.

13. *Foundations of Tungabhadra dam.*—It is not yet possible to enter in any detail into the subject of the foundations of the dam, though this is of course the key of the situation. It can only be said here that the bed of the river is granite both above and below the site. At the site a dyke of very hard compact trappoid crosses or nearly crosses the river. Near the banks the rock is overlaid by a rich alluvium with occasional outcrops of rock, trappoid, granitoid gneiss, or Dharwar schist. The abutments, where the hills on each side break off and run down, are Dharwar schist. Numerous visits to the site have been made but the river was always too high for proper inspection. It is now low and is to be examined by Mr. Bruce-Foote, the well-known Geologist, early in April. As soon as the sugarcane crops are cut pits can be dug. A diamond drill has also been ordered from England and a thorough examination will be made with it.

14. *First part of Main canal.*—The first part of the main canal is the only difficult part. It runs through very rocky and broken ground and will need the most careful designing. A fairly good line has been laid out (see plates Nos. III and IV), but it can be improved with further pains and, as already stated, the grading will have to be somewhat altered. Although this piece is difficult to design it will not in my opinion offer very great difficulties in execution except that of expense. The rocky country is certainly in places heavily fissured on the surface, but I have no doubt that this will greatly decrease in the cuttings, and that such cracks as remain will puddle up at once. Sidewalling in rocky side-long ground has been religiously avoided, except in one place where a short dam some 70 feet high will have to be made to hold up the end of a valley. Here the foundations and abutments are granite.

15. *Tunnel to Daróji.*—At 22 miles comes a point where it is necessary to depart from any alignment that has hitherto been proposed in the many surveys that have been made in this much surveyed piece of country. If the canal is continued along the valley on the line of least resistance it arrives at a place where it must either drop down into the plain and lose a great deal of command, and thereafter find infinite expense and trouble in crossing from the Hagari to the Pennér, or else it must be taken along the side of steep broken hills. There has been no hesitation in discarding both those alternatives and in striking straight into the hills through a tunnel. It is here that the value of the high offtake above river bed at the dam chiefly shows itself. It enables the tunnel to have such a fall as will reduce the section to some 650 square feet for 6,000 cusecs. Nevertheless it will be 10,000 feet along and an important undertaking.

16. *Main canal from Daróji to the Hagari.*—The tunnel debouches on to the foreshore of Daróji tank, and the level here is one of the fixed points in the line. It cannot be taken lower owing to loss of command, and the hills prevent its being kept higher. From this point to the vicinity of the Hagari there is no great difficulty. The country is mostly rolling black cotton and the canal keeps near enough to the foot of the hills to ensure cross drainage works being trifling. It has to pass close to Bellary town, and a point will be made of keeping slightly above the town for the purpose of a drinking water-supply which is badly needed.

17. *Crossing of the Hagari and passage through watershed into the Pennér.*—The crossing of the Hagari and through the watershed into the Pennér is feasible in a great many ways, and its decision will need the nicest judgment owing to the series of compromises necessary. For present purposes the canal has been brought to the Hagari at + 1,480, a distance of 70 miles from Daróji with an average fall of 0·7 foot per mile. There is also allowed a dam of about 50 feet across the Hagari, as being probably cheaper and better than running on till river and canal level meet, crossing by an aqueduct, and then running back down the other side. But this alternative must be estimated for. Allowance has also been made for an expensive cutting and tunnel straight through the watershed at the nearest point. This, it has already been ascertained, can be cheapened by taking the canal further down the right of the Hagari and crossing the watershed lower down, but there has not been time or means to decide the matter finally. It is at any rate clear that the thing can be done, and that the estimate allowed is by no means the cheapest. Several other questions, however, creep in. The route followed entails an aqueduct across the Chinna Hagari, a wide though not a very big river. It also entails the important irrigated land of Kanekal (2,000 acres) being protected by a bank, with provision for pumping out its drainage. Both these obstacles could be avoided by making the Hagari dam a few miles lower down, below the confluence of the Chinna Hagari, and this would increase the fall from Daróji and cheapen the canal. But then the crossing of the watershed into the Pennér would cost more, as the water-level would be lower. Also the distributary canal to Adóni would be lower, would cross the drainages where they were broader, and would command less country. Worst of all it might render much more expensive if not impossible the protective distributary into the Hindri valley, which is already likely to be costly in taking through the watershed. All these matters, it will be seen, demand very thorough enquiry.

There is also the question of the flood discharge of the Hagari to be examined. On the upper waters, in Mysore, the Marikanave dam has just been constructed, and the Mysore officers state that there will never be any surplus from that reservoir. This must be independently examined. If true it leaves nothing but a small catchment for the Hagari, which is in any case a poor river with small and infrequent freshes. If a cheap enough passage to the Pennér can be found it may pay to take all the Hagri water through. Otherwise there should not be much difficulty in disposing of floods.

18. *Foundations of Hagari dam.*—The Hagari is a rather wide sandy river and no examination of the foundations of a dam has been made. Rocky knolls however project from the rolling black cotton on both sides, wells show rock at 15 or 20 feet below the surface, and in escape channels of tanks and in the beds of drainages rock crops out here and there. It is probable that rock will be found at no great depth. Thorough examination must of course be made, but even without rock the dam might be of earth, or the canal taken across on an aqueduct.

19. *Water runs in bed of Pennér.*—The level of the bed of the Pennér where it runs parallel to the Hagari is lower by 100 feet or more, so that directly the water comes to the surface on the east of the watershed it drops by gravitation into the Pennér. It then runs in the bed of the Pennér to the vicinity of Tadpatri, where an anicut enables a channel to be taken off for the benefit of a corner of Anantapur district. The water then continues down the Pennér to Gandikóta. At this point a dam will be built about 90 feet above the bed of the river, to back the water up the Chitrávati which here joins the Pennér. This will enable canals to be taken off which will command land on both sides of the Pennér in the Cuddapah district. The river near Gandikóta is narrow, with steep sides of quartzite rock, and there will probably be no difficulty in constructing a dam of moderate dimensions. The maximum flood at this point is probably quite 200,000 cusecs, the disposal of which will need consideration, but is not likely to present any serious obstacle. This dam will afford a certain storage, the exact amount of which has not yet been determined, but it will probably be not more than 2,000 or 3,000 millions of cubic feet.

Anicut near Tadpatri.

Dam near Gandikóta.

Irrigation in Cuddapah.

20. *Dam at Someswaram.*—After Gandikóta the water still runs in the Pennér as far as Someswaram on the Nellore boundary, where another dam will be required. The site is apparently excellent, the river running in a narrow bed between hills of quartzite. This dam will not need to be more than about 60 feet or 70 feet above bed, and will enable a large area on both sides of the river in Nellore to be commanded. The maximum flood is here by calculation quite 450,000 cusecs, which will need probably sluices for disposal. The storage afforded by this dam will be about 10,000 millions of cubic feet.

21. *Distribution and command. Bellary West block*, 510,880 *acres.*—The main canal from Daróji to the Hagari runs along the headwaters of the drainage of the country and distributaries taken along the watersheds will affect the whole area between the hills and the Hagari. This block is called Bellary West and amounts to 510,880 acres.

Bellary East block, 760,320 *acres.*—After crossing the Hagari a canal will be run at a high level to Adóni. Branches from this westward and northward will effect the whole area between the Hagari, the Tungabhadra, and the watershed of the Hindri. This block is called Bellary East and amounts to 760,320 acres.

Hindri block, 512,640 *acres.*—Before reaching Adóni it should be possible without prohibitive expense to take a canal across the watershed into the Hindri valley. This canal has not yet been investigated. It is apparently feasible, but the approximate cost has not been ascertained. It will affect the whole Hindri valley as far as Kurnool, and this block is called the Hindri block and amounts to 512,640 acres.

Along the course of the Pennér to Tadpatri there will be a good deal of small extension of cultivation under river channels, but no block of any size.

Tadpatri block, 77,440 *acres.*—The canal from the anicut near Tadpatri has been surveyed and presents no difficulties of importance. The area affected is called the Tadpatri block and amounts to 77,440 acres.

Muddanúru block, 130,560 *acres.*—The dam at Gandikóta will back the water up the Chitrávati, from whence a canal can be taken by an expensive cutting through the Mangapatnam valley to Muddanúru. From Muddanúru the canal can be continued without difficulty to the Pápaghni, and will affect the whole area between that river and the Pennér. This is called the Muddanúru block and amounts to 130,560 acres. The same canal can then be transferred across the Pápaghni by an anicut and continued towards Cuddapah, affecting another block of 50,720 acres called the Cuddapah block.

Cuddapah block, 50,720 acres.

Jammalamadugu block, 174,080 *acres.*—From the same dam a canal can, without difficulty, be taken off to run north-eastwards, with a branch on the watershed between the Pennér and the Kunderu. This is called the Jammalamadugu block and amounts to 174,080 acres.

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Pulivendla block, 177,760 *acres.*—It should also be possible by an anicut a little higher up the Chitrávati to run a canal down the Pulivendla taluk, which will affect an area of about 177,760 acres. This canal has not yet been surveyed.

Nellore North block, 758,400 *acres.*—All the above blocks drain back into the Pennér and rejoin the main body of the water which continues down the river to Someswaram. From the Someswaram dam two canals take off at a high level. The first runs north of the river and goes without difficulty and with a good gradient to Kaligiri. Here it branches into two, keeping on the two watersheds, until it reaches the sea. The area affected is the whole country between the canal and the Pennér, as far as Kaligiri, and beyond that the country as far north as the Munnair as well. This is called the Nellore north block and amounts to 758,400 acres.

Nellore South block 687,360 *acres.*—South of the Pennér another canal takes off and runs with rather a low gradient till it attains the watershed near the point shown in the map. Here one canal continues along the watershed *viá* Sarvapalli to the sea. Another keeps southward at as high a level as possible to command the maximum of land down to the Swarnamukhi. The whole area affected is called the Nellore South block and amounts to 687,360 acres. The flow in the Pennér will further be steadied and all the numerous tanks in the Sangam and Nellore areas will be abolished.

All the above canals have been roughly surveyed except where otherwise stated.

Total area affected, 3,789,440 *acres.*—It is of course impossible at this stage to say how much of the area affected is commanded, how much commanded is irrigable, and still less how much that is irrigable is likely to be irrigated. What may be said with certainty is that a tract of $3\frac{3}{4}$ million acres or nearly 6,000 square miles will never again know famine.

APPROXIMATE COST.

22. *Cost of works.*—Approximate estimates of all the above works have been made, but although all possible pains have been taken they cannot be accepted as anything but very rough. A great deal more investigation is needed before detailed plans and estimates can be prepared. The following figures however will do as a basis for discussion. As far as they go it is believed that they are not an underestimate. They are for an offtake of 6,000 cusecs from the Tungabhadra.

Works.

	RS.
Tungabhadra dam	80,00,000
" sluices	20,00,000
Main canal, 24 miles	48,00,000
Tunnel, 10,000 feet to Daróji	30,00,000
Main canal, 70 miles to Hagari	35,00,000
Hagari dam...	20,00,000
* Cutting through watershed, $5\frac{3}{4}$ miles	16,00,000
* Tunnel " 12,000 feet	36,00,000
Anicut for Tadpatri block	3,00,000
Gundikota dam	40,00,000
" sluices	10,00,000
Mangapatnam cutting	20,00,000
Someswaram dam	40,00,000
" sluices...	15,00,000
Compensation	40,00,000
Total ...	4,53,00,000

* NOTE.—A section showing a passage costing only 16 lakhs is forwarded (plate No. VII).

23. *Possible distributaries required.*—Until the extent and method of irrigation is decided, it is of course impossible to estimate the cost of distributaries. As it is necessary to start with some sort of idea, however rough, of what is possible or not improbable, a guess may be hazarded that 500,000 acres of wet land will be irrigated, and that 1,500,000 acres of dry land will be either watered or protected. The cost of distributaries would then be—

Possible distributaries required.

	RS.
500,000 acres wet at Rs. 20	1,00,00,000
1,500,000 " dry at " 6	90,00,000
Total ...	1,90,00,000

The total for works would then amount to Rs. 6,43,00,000. The charge for establishment and tools and plant, being taken roughly at a quarter of this amount and contingencies at 10 per cent., the grand total would amount in round figures to 870 lakhs.

RETURNS.

24. *Returns.*—With these figures of cost and area affected, it is possible to make any number of calculations of returns, all equally unreliable. The analogy of the Kurnool canal can be used, or the analogy of the Periyár project, or the analogy of the great deltas, or any number of combinations of these object lessons. It is obvious that a Revenue officer, in whom the Government can place complete confidence, must be appointed, to make enquiry and to recommend a policy. There are three main lines which it is possible to follow. The project may be regarded as a money-making concern, in which case irrigation must be pushed in every possible manner, resort must be had to colonisation if the indigenous population is unable or unwilling to completely utilise the water, an insurance rate on dry land protected must be levied. Or the project may be regarded as philanthropic concern, and it may be determined to stand the risk of losing all or most of the interest on the capital expended, merely in order to protect the famine-affected tracts. There may, of course, be compromises between these two lines of policy, varying in different districts, but in each tract one or other must in general be followed. The third course which remains is to abandon the scheme as too risky or too expensive for the benefits likely to accrue; as to which it can only be said that if the work is not done now it will be done hereafter. It is inconceivable that our descendants will for ever allow all this water to run waste into the sea.

At this stage it is useless to enter into all the arguments for any particular policy. If, however, it is urged that the people are not in a state yet to take advantage of the benefits afforded them, and if on this ground it is sought to defer the project to a period when the population becomes more numerous and more wealthy, better equipped in capital, live-stock, and labour for the state of life to which the Government will then call them, it will have to be always remembered that without water this happy condition of things can never arrive, and that it is water and water alone which can render the people capable of utilising water. In the consideration of these matters, the Kurnool canal will be doubtless extensively drawn upon as a precedent, and it is well that this particular example should be given its proper value. It is everywhere quoted, and without contradiction, as an irrefutable example of the futility of supplying water to a tract which combines the disadvantages of a sparse population and a black-cotton soil. As to these disabilities it may be stated at once that much of the soil is not black cotton and yet it is not irrigated, and further that there is no proof that black-cotton soil cannot be irrigated. It can certainly be watered for dry crops with immense advantage. It may moreover be confidently asserted that in time—in the course of generations but nevertheless eventually—all the irrigable land will be irrigated, and that without water the people would never have been in a position to do it. The principal cause of the paucity of irrigation under the Kurnool canal can be nothing else but the sparseness of population and the poverty of the people. The reason for this is the want of water, and nothing but water can remedy it. To argue that because a tract is poor and sparsely populated therefore water must not be given it, is to argue in a vicious circle. That the expense will not be repaid is another and quite a fair line of reasoning; though no one can travel in Kurnool and observe the difference between protected and unprotected tracts without believing that almost any conceivable sums are well laid out in such a cause.

Even in this regard, as to the expense involved, the accounts of the Kurnool canal must not, as they stand, be accepted as a fair criterion of what would be the result under similar conditions elsewhere. The canal was built by a company under a Government guarantee of 5 per cent. (in itself a heavy charge), and those who have observed the methods of companies with a free hand and no responsibility can imagine the extravagance and the malversation which took place during construction. An instance is on record of contracts being given out at three times the estimate rate while the estimate had only that moment been prepared and was still unsanctioned. Instances of bad work pulled down and rebuilt were numerous and glaring. There were instances, too, of over-hasty commencement of execution, afterwards found unsuitable, and abandoned. The waste in these processes cannot be calculated, but it may be asserted at a guess that the works could have been constructed for 25 per cent. less than was actually expended. It is not necessary to descant on the faults of alignment, by which unsuitable land was commanded and suitable land omitted. This was an excusable mistake under the circumstances, only noteworthy in order to be avoided in the future. But the crying extravagance was the combination of navigation and irrigation. The navigation portion of the canal was far the more expensive of the two, and had it been omitted the returns would have assumed a vastly different complexion. For convenience of illustration, though with no pretence to precision, the following calculation is made :—

Real cost of Kurnool canal—

	RS.
Sum paid for canal...	1,74,22,460
Deduct 25 per cent. for extravagance and malversation in construction	43,55,615
True cost ...	1,30,66,845
Deduct cost of navigation canal where not obligatory for irrigation	65,66,845
	65,00,000

	RS.
If this money were borrowed now the interest would be perhaps $3\frac{1}{2}$ per cent. Allowing for interest on interest during development, the interest on 65 lakhs at, say, 5 per cent. is ...	3,25,000
Working expenses without navigation, 1900-1901	50,000
Total annual charges ...	3,75,000
Revenue, 1900-1901	1,77,647
Annual loss ...	1,97,353

This is the light in which it should be regarded at the present day and few will deny that an expenditure of 2 lakhs per annum is cheap for the protection enjoyed by a considerable tract of country, which before suffered severely, even on the score of the cash cost of relief, the dislocation of business, the strain on official *personnel*. None who are able to compare the appearance of this tract and its population with similar unprotected areas in the same district can feel a doubt about the matter.

There is a great deal more that might be said on this topic of returns. Enough has been written at any rate to indicate the momentous nature of the question, the enormous financial and human interests involved, the obstacles to a correct conclusion, and the extent to which the Government must rest upon the officer deputed for its settlement. It should also not be lost sight of that there is quite a possibility of the project turning out to be not merely protective but also productive, in the official acceptation of these terms. There will be but little irrigation in Bellary, but in parts of Cuddapah irrigation is welcome and also in Nellore, and in the latter district experiments on the irrigation of a double dry crop are commencing. It is then for instance quite possible that out of the great area affected the following results might accrue :—

Possibility of this project proving a "productive" Public Works.

	RS.
500,000 acres wet at Rs. 4	20,00,000
200,000 „ second crop at Rs. 2	4,00,000
750,000 „ double dry crop at Rs. 4	30,00,000
750,000 „ dry crop insured at Re. 1	7,50,000
Total ...	61,50,000

which is over 7 per cent. on Rs. 870 lakhs.

25. *Power.*—There will be a certain amount of power available at Hospet, Hagari, Gandikota and Someswaram, but this is a very minor matter and need not be discussed here.

26. *Conclusion.*—This concludes the preliminary report. It has been purposely kept as bald and brief as possible. Discussion of debateable points merely obscures the general view, and is of little service until far deeper investigation has been carried out. The proposition statement of establishment required for this is made out separately with an explanatory note.

(Signed) A. T. MACKENZIE,
Ex. Engr., Tungabhadra-Pennér Projects.

Note.—The following plans accompany this report :—

	PLATES.
General plan in four sheets	
Plan of Tungabhadra reservoir	I
Section at site of Tungabhadra dam	II
Canal line from reservoir to Daróji	III
Section of reservoir to Daróji	IV
Hagari-Pennér watershed, plan	V
Section through „ direct	VI
Do. alternative route	VII
* Tadpatri canal, section	VIII
* Section of Pennér river near Gandikota	IX
* Jammalamadugu canal, section	X
* Muddanur canal, section	XI
* Cuddapah „ „	XII
Section of Pennér river at Someswaram	XIII
* Nellore north canal, section	XIV
* Do. south „ „	XV
Papinaikanhalli route, section	XVI

* Will follow.

FINAL REPORT ON THE TUNGABHADRA PROJECT.

The preceding papers give chronologically and in sufficient detail a history of the circumstances which have led up to the present report. The preliminary report, which was submitted to the Government of Madras in April 1903, was accompanied by an estimate of the further establishment required to make surveys in detail and complete designs and estimates. This was sanctioned in May 1903 and the operations contemplated lasted till October 1904, resulting in the plans and estimates now submitted.

The scheme though large in the aggregate contains no engineering features of overwhelming magnitude or of a nature that has not already been justified by experience. Consequently its description need not be unduly prolonged, since there are no portions demanding elaborate defence or explanation. The main lines have not departed materially from those sketched in the preliminary report. There have however naturally been considerable alterations in the component parts, and it is therefore necessary in spite of recapitulation to describe the project *de novo*.

2. *General features.*—The project hinges on the dam across the Tungabhadra river, which will be at Malapuram, 3 miles above Hospet. From this a canal will take off running *viâ* Nelapur and Uparhalli, and thence by a tunnel to the foreshore of Darôji tank. From this point the canal will run past Bellary town to the Hagari river, will cross the Hagari, pierce the Hagari-Pennér watershed, and so drop into the Pennér river, along the course of which it will run to a reservoir on the boundary of the Nellore district.

3. *Tungabhadra dam and reservoir.*—The bed of the Tungabhadra for purposes of storage may be taken at 1,500 feet above mean sea level, though there is a narrow channel which goes down to + 1,476. The exigencies of the main canal oblige the offtake to be not lower than + 1,580, so that all storage to be used by the canal must be above this level. The level of full supply in the reservoir will be + 1,630, giving a total storage of 120,680 millions of cubic feet, of which 13,900 millions will be below offtake level. The top of the dam will be at + 1,640, and above that a 3-foot parapet. The area submerged will be 138$\frac{1}{8}$ square miles, of which 75$\frac{9}{16}$ square miles is in the Madras Presidency, 57$\frac{1}{2}$ square miles in the Nizam's dominions, and 5$\frac{1}{16}$ square miles in the Bombay Presidency. The details of land and villages drowned will be seen in the Revenue officer's report.

The table below gives the capacity and area at 10-foot vertical intervals above the offtake level :—

	Capacity of reservoir in millions of cubic feet.	Area of waterspread, square miles.
Level + 1,580	13,900	29$\frac{9}{16}$
„ + 1,590	23,875	42
„ + 1,600	38,076	59$\frac{7}{8}$
„ + 1,610	58,288	85$\frac{1}{8}$
„ + 1,620	85,791	112$\frac{3}{16}$
„ + 1,630	120,683	138$\frac{1}{8}$

4. *Floods and their disposal.*—It was originally intended to pass excess water by sluices in the body of the dam, as at Assuan, in the belief that no high level escape was available. But since leave has been obtained to survey in the Nizam's dominions, it has been found that a portion of the hills which wall in the reservoir can be utilised as an escape. It would be by no means impossible to pass floods through the dam, but the other method is considered so superior that it was at once adopted. The lowest level at which it is practicable to form the high level escape is + 1,600, and the configuration of the hills entails a depth of 30 feet of water to pass the maximum flood. This fixes + 1,630 as full supply level in the reservoir.

The catchment basin is 10,600 square miles and consists to a certain extent of hilly country with a copious rainfall, but is mostly dry and undulating. The rainfall throughout the basin is chiefly due to the south-west monsoon. In designing the escape the worst possible concatenation of circumstances has of course been anticipated, namely, the maximum flood occurring with the reservoir full. The maximum flood to be expected from such a catchment would be about 217,570 cubic feet per second, with a co-efficient of 450 in Ryves' formula $Q = C M^{\frac{2}{3}}$. In the present case provision has been made for a discharge of 345,000 cubic feet a second, by 30 vents with floor level at + 1,600, built on a saddle about a mile to the north of the dam. Each vent will have a 40 feet span and the depth of water allowed for in the vent is 26 feet. The gates will be 30 feet high, so that when the reservoir is full and the gates raised 26 feet there will be a head of 4 feet on them. The escape water will find its own way back to the river-bed. Should the maximum discharge provided for be exceeded, the rise of water in the reservoir will cause a greater head on the gates and increase the discharge; and there will moreover be nine low level sluices in the body of the dam, which will be hereafter referred to.

5. *Foundations of the dam.*—The foundations have been examined by two experienced geologists, whose reports are subjoined (see appendix, page 49). The rock on which the dam is to be built is a very hard compact trappoid, containing some broad intrusive pegmatite bands which are also extremely hard and massive. The trappoid rock runs in a broad band across the river and into the hills on either side and forms an excellent foundation. Careful borings and excavations have been taken to determine the levels at which sound rock will be met with.

6. *Material.*—The dam will be built of uncoursed rubble in mortar. There will be a facing on both up-stream and downstream sides of granitoid gneiss, of which there is plenty in the immediate vicinity. The hearting will be of selected trappoid, of which the supply is plentiful and on the spot. The mortar will consist of Kunkur lime, surki, and river sand. Lime and surki can be obtained in the immediate neighbourhood, and tests of their cost and behaviour are being made. Sand will have to be brought by rail and its use must be restricted.

The floors of the low level sluices (see paragraph 13) and of the main canal head sluice (see paragraph 16) will be of selected superior trap, which is present in dykes of fine quality within 7 miles.

7. *Section of dam.*—The section has been calculated by the formulæ recommended in Wegmann's "Masonry Dams", *viz.*, (1) $d = a\sqrt{r}$, (2) $x^2 + \left(\frac{4w}{h} + l\right)x = \frac{6}{h}(wm + M) + l^2$ and (3) $x^2 + x\left(\frac{2w}{h} + l\right) = \frac{6M}{h}$, and the nearest practical section has been taken. The weight of masonry is taken as 140 lbs per cubic foot which is probably somewhat less than actual, and the limiting intensity of pressure 10 tons per square foot. There will be nine low level sluices, and for this portion the calculations have been made on the lines laid down by Sir B. Baker for the Assuan dam, that is, the piers between the vents are made capable of withstanding the water pressure without the assistance of the masonry above the vents.

8. *Offtake level.*—The floors of the main canal head sluices and the bed of the main canal at head will be at + 1,580, with full supply level in the canal + 1,600. This allows full advantage of the storage to be taken with a minimum height of dam and reduces to the utmost the quantity of idle water below offtake. A level of offtake still lower makes the main canal more difficult and expensive. The level selected combines the greatest number of advantages and fits in well with the provision made for the disposal of floods.

9. *Storage.*—There are complete records of the water passing over Sunkesula anicut 121 miles below the site of the dam, at the head of the Kurnool-Cuddapah canal for 25 years. A summary of these records, month by month, is as follows :—

Months.	1877–78.	1878–79.	1879–80.	1880–81.	1881–82.	1882–83.	1883–84.	1884–85.	1885–86.
1	2	3	4	5	6	7	8	9	10
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	..	1,000	..	3,000	1,000	1,000	1,000	1,000	2,000
May	5,000	5,000	3,000	..	5,000	4,000	3,000	1,000	7,000
June	43,000	7,000	8,000	1,000	8,000	64,000	11,000	..	30,000
July	104,000	34,000	119,000	123,000	35,000	232,000	162,000	50,000	120,000
August ..	80,000	112,000	144,000	68,000	87,000	29,000	116,000	131,000	156,000
September ..	85,000	111,000	61,000	34,000	31,000	6,000	206,000	84,000	65,000
October ..	140,000	85,000	15,000	61,000	28,000	1,000	82,000	43,000	70,000
November ..	43,000	23,000	6,000	40,000	10,000	..	39,000	8,000	..
December ..	11,000	1,000	..	9,000	..	..	152,000	..	..
January ..	4,000	2,000	1,000	4,000	2,000	..	4,000	2,000	1,000
February ..	..	..	..	..	..	..	1,000	..	..
March ..	..	..	..	..	..	..	..	1,000	..
Total ..	515,000	[illegible]38,000	357,000	343,000	207,000	337,000	777,000	321,000	451,000

Months.	1886–87.	1887–88.	1888–89.	1889–90.	1890–91.	1891–92.	1892–93.	1893–94.	1894–95.
	11	12	13	14	15	16	17	18	19
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	1,000	1,000	7,000	2,000	2,000	..	..	1,000	1,000
May	23,000	[illegible]	14,000	3,000	8,000	4,000	6,000	9,000	7,000
June	73,000	66,000	28,000	43,000	18,000	13,000	34,000	41,000	18,000
July	130,000	172,000	194,000	128,000	110,000	87,000	169,000	67,000	58,000
August ..	118,000	82,000	[illegible]	131,000	110,000	[illegible]	134,000	77,000	84,000
September ..	79,000	86,000	52,000	209,000	24,000	31,000	119,000	50,000	24,000
October ..	82,000	61,000	24,000	151,000	29,000	36,000	48,000	69,000	20,000
November ..	31,000	44,000	61,000	13,000	67,000	7,000	1,000	10,000	9,000
December ..	..	10,000	3,000	3,000	6,000	5,000	3,000	..	..
January ..	2,000	71,000	2,000	2,000	2,000	1,000	3,000	not available.	..
February ..	..	1,000	..	..	..	..	..		..
March ..	..	..	..	..	..	..	3,000		..
Total ..	539,000	536,000	541,000	685,000	376,000	277,000	520,000	324,000	221,000

Months.	1895–96.	1896–97.	1897–98.	1898–99.	1899–1900.	1900–1901.	1901–1902.	Average.
	20	21	22	23	24	25	26	27
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	2,000	..	1,000	1,000	7,000	..	..	1,000
May	5,000	3,000	..	6,000	8,000	7,000	17,000	6,000
June	32,000	47,000	89,000	47,000	45,000	28,000	45,000	23,000
July	71,000	190,000	93,000	109,000	93,000	280,000	175,000	124,000
August	100,000	321,000	213,000	144,000	45,000	268,000	170,000	127,000
September	34,000	44,000	164,000	116,000	106,000	95,000	60,000	79,000
October	45,000	34,000	29,000	132,000	30,000	54,000	67,000	60,000
November	13,000	25,000	17,000	62,000	4,000	16,000	20,000	23,000
December	..	7,000	5,000	20,000	..	6,000	5,000	10,000
January	..	..	..	15,000	..	1,000	1,000	2,000
February	..	..	..	1,000	..	11,000	..	1,000
March	..	..	..	..	..	1,000	..	..
Total ..	302,000	671,000	681,000	653,000	338,000	769,000	560,000	466,000

Between the proposed site of dam and Sunkesula, the Hagari joins the Tungabhadra and the water contributed by that river will not be available for storage. A deduction should be made on this account, but the quantity is hard to decide. The Hagari is a most uncertain river and in bad years almost a negligible quantity. In good years the quantity available in the Tungabhadra is so much greater than the quantity it is proposed to store, that the proportion contributed by the Hagari need not be considered. Further, the regulator by which the main canal is taken across the Hagari higher up will catch the normal flow and enable it to be utilised in the canal. On these grounds, the records at Sunkesula have been accepted as sufficiently correct at Malapuram for practical purposes.

The following table gives the surplus of the Kistna at Bezwada anicut for a series of years, monthly :—

Months.	1877–78.	1878–79.	1879–80.	1880–81.	1881–82.	1882–83.	1883–84.	1884–85.
1	2	3	4	5	6	7	8	9
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	..	3,000	9,000	5,000	5,000	5,000	9,000	7,000
May	2,000	9,000	11,000	4,000	5,000	3,000	11,000	11,000
June	39,000	2,000	23,000	47,000	26,000	613,000	178,000	3,000
July	71,000	35,000	99,000	568,000	450,000	1,063,000	887,000	498,000
August	85,000	168,000	134,000	373,000	622,000	601,000	544,000	782,000
September	95,000	104,000	76,000	376,000	280,000	640,000	703,000	633,000
October	102,000	122,000	40,000	278,000	397,000	383,000	55,000	413,000
November	44,000	85,000	25,000	223,000	23,000	227,000	138,000	181,000
December	24,000	20,000	16,000	148,000	9,000	77,000	21,000	69,000
January	10,000	157,000	22,000	9,000	5,000	11,000	12,000	20,000
February	1,000	4,000	2,000	..	..	1,000	5,000	1,000
March	..	20,000	1,000	2,000	6,000	10,000	5,000	17,000
Total ..	473,000	679,000	458,000	2,033,000	1,828,000	3,534,000	2,568,000	2,635,000

Months.	1885–86.	1886–87.	1887–88.	1888–89.	1889–90.	1890–91.	1891–92.	1892–93.
	10	11	12	13	14	15	16	17
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	9,000	6,000	7,000	14,000	4,000	3,000	8,000	7,000
May	10,000	6,000	9,000	37,000	13,000	16,000	5,000	4,000
June	38,000	240,000	273,000	113,000	136,000	109,000	23,000	261,000
July	51,000	740,000	1,523,000	1,619,000	94,000	1,317,000	497,000	1,153,000
August	827,000	780,000	782,000	1,103,000	925,000	1,491,000	1,252,000	997,000
September	566,000	430,000	779,000	48,000	1,037,000	394,000	405,000	1,660,000
October	690,000	642,000	402,000	293,000	1,184,000	218,000	295,000	747,000
November	194,000	251,000	212,000	75,000	127,000	118,000	15,000	644,000
December	222,000	149,000	64,000	36,000	57,000	21,000	..	42,000
January	71,000	25,000	45,000	4,000	23,000	..	..	185,000
February	3,000	11,000	11,000	..	3,000	..	..	123,000
March	8,000	10,000	12,000	9,000	6,000	6,000	6,000	71,000
Total ..	2,692,000	3,290,000	4,119,000	3,351,000	3,609,000	3,695,000	2,506,000	5,894,000

Months.	1893–94.	1894–95.	1895–96.	1896–97.	1897–98.	1898–99.	1899–1900.	1900–1901.
	18	19	20	21	22	23	24	25
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	14,000	9,000	7,000	3,000	..	..	10,000	..
May	11,000	11,000	10,000	..	2,000	8,000	13,000	..
June	677,000	160,000	10,000	203,000	161,000	176,000	89,000	65,000
July	717,000	1,389,000	508,000	615,000	463,000	541,000	246,000	733,000
August	1,087,000	697,000	827,000	1,292,000	891,000	568,000	103,000	1,020,000
September	834,000	505,000	775,000	121,000	489,000	438,000	293,000	223,000
October	737,000	263,000	416,000	43,000	440,000	333,000	17,000	141,000
November	124,000	167,000	109,000	16,000	28,000	69,000	..	5,000
December	22,000	23,000	18,000	21,000	..	12,000	..	..
January	Not available.	1,000	2,000	..	..	1,000	..	..
February		1,000	1,000	..	..	..	..	8,000
March		2,000	6,000	1,000	1,000	1,000	..	2,000
Total ..	4,223,000	3,228,000	2,689,000	2,345,000	2,475,000	2,147,000	771,000	2,197,000

The whole of this surplus flows to waste into the sea. Consequently, when the surplus at Bezwada is equal to or greater than the surplus in the same month at Sunkesula, the whole of the Sunkesula surplus can be stored, without doing any harm to the *Kistna delta*. If however the surplus at Bezwada in any month is less than that at Sunkesula, it means that the difference is being used above the Bezwada anicut, and this difference must be deducted from the amount of Sunkesula surplus available for storage. Applying these deductions the following table represents the quantity available for storage :—

Months.	1877-78.	1878-79.	1879-80.	1880-81.	1881-82.	1882-83.	1883-84.	1884-85.
1	2	3	4	5	6	7	8	9
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	..	1,000	..	3,000	1,000	1,000	1,000	1,000
May	2,000	5,000	3,000	..	5,000	3,000	3,000	1,000
June	39,000	2,000	8,000	1,000	8,000	64,000	11,000	..
July	71,000	31,000	99,000	123,000	35,000	232,000	162,000	50,000
August	80,000	119,000	134,000	68,000	87,000	29,000	116,000	131,000
September	85,000	194,000	61,000	34,000	31,000	6,000	206,000	84,000
October	1,02,000	55,000	15,000	61,000	28,000	1,000	55,000	43,000
November	43,000	23,000	6,000	40,000	10,000	..	39,000	8,000
December	11,000	1,000	..	9,000	..	..	21,000	..
January	4,000	2,000	1,000	4,000	2,000	..	4,000	2,000
February	..	..	..	..	..	..	1,000	..
March	..	..	..	..	..	..	..	..
Total ..	437,000	376,000	327,000	343,000	207,000	336,000	619,000	3,20,000

Months.	1885-86.	1886-87.	1887-88.	1888-89.	1889-90.	1890-91.	1991-92.	1892-93.
	10	11	12	13	14	15	16	17
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	2,000	1,000	1,000	7,000	2,000	2,000	..	..
May	7,000	6,000	8,000	14,000	3,000	8,000	4,000	4,000
June	30,000	73,000	60,000	28,000	43,000	18,000	13,000	34,000
July	120,000	130,000	172,000	194,000	128,000	110,000	87,000	169,000
August	156,000	118,000	82,000	156,000	131,000	110,000	93,000	134,000
September	65,000	79,000	86,000	52,000	209,000	34,000	31,000	119,000
October	70,000	82,000	61,000	24,000	151,000	29,000	36,000	48,000
November	..	31,000	44,000	61,000	13,000	67,000	7,000	10,000
December	..	..	10,000	3,000	3,000	6,000	..	3,000
January	1,000	2,000	10,000	2,000	2,000	..	..	..
February	..	..	1,000	..	..	..	..	[illegible]
March	..	..	..	..	..	..	..	3,000
Total ..	451,000	522,000	535,000	541,000	685,000	3,84,000	271,000	527,000

Months.	1893-94.	1894-95.	1895-96.	1896-97.	1897-98.	1898-99.	1899-1900.	1900-1901.	Average.
	18	19	20	21	22	23	24	25	
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	1,000	1,000	2,000	..	..	..	7,000	..	1,000
May	9,000	7,000	5,000	3,000	..	6,000	8,000	..	5,000
June	41,000	18,000	10,000	47,000	89,000	47,000	45,000	28,000	32,000
July	67,000	58,000	71,000	190,000	93,000	109,000	93,000	280,000	120,000
August ..	77,000	84,000	100,000	321,000	213,000	144,000	45,000	268,000	125,000
September ..	50,000	24,000	34,000	44,000	164,000	116,000	106,000	95,000	80,000
October ..	69,000	21,000	45,000	34,000	99,000	132,000	17,000	54,000	57,000
November ..	10,000	9,000	13,000	16,000	17,000	62,000	..	5,000	22,000
December ..	..	..	..	7,000	..	12,000	..	..	4,000
January ..	..	..	..	..	..	1,000	..	..	2,000
February ..	..	..	..	..	..	..	..	8,000	400
March ..	..	..	..	..	..	..	..	..	..
Total ..	324,000	222,000	280,000	662,000	675,000	629,000	321,000	738,000	

From these tables it will be seen that the minimum available according to present records is 207,000 millions of cubic feet. If the worst known year in the Tungabhadra and the worst known year (1879-80) in the Kistna had happened to coincide, there would be in that year 20[illegible],000 millions cubic feet for storage, without abstracting any water that does not now flow to waste in the sea.

It will further be seen that there will always be ample water for any reservoir that may be constructed on the Kistna above Bezwada.

The table below gives corresponding figures for the Penner river. This shows that there is generally no water available in that river early in the irrigation season, that is in the month of June, and it must be supplied from the Tungabhadra. The bed level of offtake canal from Tungabhadra reservoir has been fixed at + 1,580, and the level of the reservoir must therefore not be allowed to fall below + 1,580, if water is to be sent to the Penner directly the season opens. The result of this is that the water stored below + 1,580 is idle and cannot be utilised.

Months.	1877-78.	1878-79.	1879-80.	1880-81.	1881-82.	1882-83.	1883-84.	1884-85.
1	2	3	4	5	6	7	8	9
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	..	..	..	..	..	..	..	..
May	8,000	..	26,000	..	..	1,000	..	..
June	9,000	7,000	18,000	4,000	1,000	..	4,000	..
July	..	32,000	9,000	1,000	1,000	1,000	4,000	..
August	1,000	44,000	46,000	18,000	16,000	4,000	27,000	1,000
September	35,000	64,000	29,000	27,000	22,000	24,000	4,000	2,000
October	51,000	105,000	16,000	21,000	23,000	26,000	57,000	38,000
November	46,000	42,000	32,000	53,000	26,000	44,000	69,000	85,000
December	3,000	10,000	2,000	36,000	4,000	53,000	28,000	45,000
January	2,500	1,000	1,000	2,000	7,000	6,000	4,000	13,000
February	1,000	1,000	1,000	1,000	1,000	1,000	2,000	1,000
March	..	1,000	..	1,000	..	1,000	1,000	1,000
Total ..	159,000	307,000	180,000	161,000	101,000	161,000	200,000	186,000

Months.	1885-86.	1886-87.	1887-88.	1888-89.	1889-90.	1890-91.	1891-92.	1892-93.
	10	11	12	13	14	15	16	17
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	..	..	..	..	..	..	..	..
May	1,000	..	..	..	..	..	..	..
June	2,000	..	..	..	..	..	..	8,000
July	8,000	1,000	7,000	..	10,000	..	..	33,000
August	18,000	29,000	19,000	..	14,000	7,000	2,000	39,000
September	17,000	1,000	60,000	..	57,000	16,000	..	78,000
October	34,000	48,000	38,000	7,000	104,000	23,000	4,000	79,000
November	36,000	32,000	67,000	47,000	16,000	22,000	..	32,000
December	31,000	3,000	41,000	8,000	5,000	2,000	..	2,000
January	4,000	1,000	9,000	2,000	4,000	1,000	..	1,000
February	1,000	2,000	1,000	1,000	..	..	..	..
March	1,000	..	..	1,000	..	..	..	1,000
Total ..	156,000	117,000	242,000	66,000	210,000	71,000	6,000	273,000

Months.	1893-94.	1894-95.	1895-96.	1896-97.	1897-98.	1898-99.	1899-1900.	1900-1901.	Average.
	18	19	20	21	22	23	24	25	26
	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.	MILS. C. FT.
April	..	..	..	..	..	..	1,000	..	..
May	..	..	..	..	..	..	..	..	1,500
June	..	..	..	..	1,000	1,000	..	..	2,300
July	13,000	7,000	..	..	3,000	..	..	12,000	6,000
August ..	3,000	27,000	1,000	4,000	11,000	1,000	..	1,000	14,000
September ..	6,000	35,000	29,000	1,000	44,000	33,000	23,000	41,000	27,000
October ..	42,000	31,000	60,000	..	25,000	14,000	4,000	14,000	36,000
November ..	86,000	64,000	19,000	9,000	1,000	39,000	8,000	1,000	36,000
December ..	6,000	1,000	1,000	2,000	1,000	19,000	..	1,000	13,000
January ..	..	..	13,000	1,000	1,000	2,000	..	1,000	3,000
February ..	..	..	..	..	..	1,000	..	..	600
March ..	..	..	..	..	..	..	..	..	300
Total ..	156,000	165,000	123,000	17,000	87,000	110,000	36,000	71,000	139,700

Note applicable to Table of Working of Reservoir.

I. After a deduction for Kurnool canal of 7,800 millions cubic feet for the months of June to November and 2,600 millions cubic feet for the months of December to February and less Bezwada as explained in note (*a*), the balance has been taken as quantity available for storage in the reservoir in column 2.

(*a*) Less Bezwada means that when the surplus at Bezwada is less than that at Sunkesala, the difference in defect has been deducted from the quantity available for storage in the Tungabhadra reservoir, and the net resulting quantity has been entered in the statement.

II. 5,200 millions cubic feet are required for power. This full quantity is available from June to November when the 7,800 millions cubic feet is passed for the Kurnool-Cuddapah canal; but from December to February 2,600 millions cubic feet will be passed for power in addition to the 2,600 millions cubic feet required for the Kurnool-Cuddapah canal.

The following table shows the condition of the Tungabhadra reservoir month by month during an average year, coinciding with the worst known year in the Pennér :—

End of	Supply or net quantity available in Tungabhadra for storage after deducting for Kurnool canal; and less Bezwada.	Deduct for power.	Supply available in Pennér.	Required for 400,000 acres first crop and 100,000 acres second crop in Nellore.	Required from Tungabhadra reservoir.	Required for 400,000 acres first crop and 50,000 acres second crop in Cuddapah, etc.	Required for one million acres dry protected = 8,000 millions cubic feet per month.	Total demand.	Level of Tungabhadra reservoir.	Less evaporation.
1	2	3	4	5	6	7	8	9	10	11
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.		
March	..	..	..	..	..	..	..	..	+ 1,590	..
April	1,000	5,200	..	..	..	..	..	5,200	+ 1,58[illegible]	+ 1,58[illegible]
May	5,000	5,200	..	..	..	..	..	5,200	+ 1,585	+ 1,584
June	32,000	..	..	10,400	10,400	10,400	..	20,800	+ 1,591	+ 1,590
July	120,000	..	..	10,400	10,400	10,400	..	20,800	+ 1,630	+ 1,630
August	125,000	..	2,000	10,400	8,400	10,400	8,000	26,800	+ 1,630	+ 1,630
September	80,000	..	..	10,400	10,400	10,400	8,000	28,800	+ 1,630	+ 1,630
October	57,000	..	4,000	10,400	6,400	10,400	8,000	24,800	+ 1,630	+ 1,630
November	22,000	..	..	10,400	10,400	10,400	8,000	28,800	+ 1,628	+ 1,627
December	4,000	2,600	..	2,600	2,600	1,300	..	6,500	+ 1,625	+ 1,624
January	2,000	2,600	..	2,600	2,600	1,300	..	6,500	+ 1,623	+ 1,622
February	400	2,600	..	2,600	2,600	1,300	..	6,500	+ 1,620	+ 1,619
March	..	5,200	..	..	..	..	..	5,200	+ 1,617	+ 1,616

It will be seen that all the proposed irrigation is steadily supplied, that an assumed famine demand of protection for 1,000,000 acres of dry crop is also dealt with, and that a contribution is given for the development of power during the months when water is not normally passed down for the Kurnool canal. All these demands are successfully met, and the reservoir finishes with a good deal more water than it contained at starting. The Pennér year is peculiarly bad, being nearly three times as bad as the next worst, and very greatly indeed below average.

The next table shows the condition of the Tungabhadra reservoir month by month during the worst known year, coinciding with an average year in the Pennér.

End of	Supply or net quantity available in Tungabhadra for storage after deducting for Kurnool canal and less Bezwada.	Deduct for power.	Supply available in Pennér.	Required for 400,000 acres first crop and 100,000 acres second crop in Nellore.	Required from Tungabhadra reservoir.	Required for 400,000 acres first crop and 50,000 acres second crop in Cuddapah, etc.	Required for 1 million acres dry protected = 8,000 millions cubic feet per month.	Total demand.	Level of Tungabhadra reservoir.	Less evaporation.
1	2	3	4	5	6	7	8	9	10	11
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.		
March	..	..	..	..	..	..	..	..	+ 1,590	..
April	1,000	5,200	..	..	..	..	..	5,200	+ 1,586	+ 1,585
May	5,000	5,200	1,500	..	..	..	..	5,200	+ 1,58[illegible]	+ 1,5[illegible]
June	8,000	..	2,300	10,400	8,100	10,400	..	18,500	Dry.	
July	35,000	..	6,000	10,400	4,400	10,400	..	14,800	+ 1,596	+ 1,595
August	87,000	..	14,000	10,400	..	10,400	8,000	18,400	+ 1,624	+ 1,623
September	31,000	..	27,000	10,400	..	10,400	8,000	18,400	+ 1,627	+ 1,626
October	28,000	..	36,000	10,400	..	10,400	8,000	18,400	+ 1,629	+ 1,628
November	10,000	..	36,000	10,400	..	10,400	8,000	18,400	+ 1,625	+ 1,624
December	..	2,600	13,000	2,600	..	1,300	..	3,900	+ 1,623	+ 1,622
January	2,000	2,600	3,000	2,600	..	1,300	..	3,900	+ 1,621	+ 1,620
February	..	2,600	600	2,600	..	1,300	..	3,900	+ 1,619	+ 1,618
March	..	5,200	300	..	..	..	..	5,200	+ 1,616	+ 1,615

In this case the reservoir is assumed to start at + 1,590 and runs dry for most of June. This shows the necessity of not letting the Tungabhadra reservoir fail below + 1,600 on 1st April. The case can in reality never be so bad as shown, because the Cuddapah and Nellore demand will not begin till middle of June and will then be only partial, and because further the power water sent down in April and May will pass through the Kurnool canal into the Pennér reservoir. Even neglecting these ameliorations the Tungabhadra reservoir finishes well.

The last and most trying case is that of the worst known year in the Tungabhadra coinciding with the worst known year in the Pennér, a case which has never yet happened. This is analysed in the following table :—

End of	Supply or net quantity available in Tungabhadra for storage after deducting for Kurnool canal and less Bezwada.	Deduct for power.	Supply available in Pennér.	Required for 400,000 acres first crop and 100,000 acres second crop in Nellore.	Required from Tungabhadra reservoir.	Required for 400,000 acres first crop and 50,000 acres second crop in Cuddapah, etc.	Required for 1 million acres dry protected = 8,000 millions cubic feet per month.	Total demand.	Level of Tungabhadra reservoir.	Less evaporation.
1	2	3	4	5	6	7	8	9	10	11
	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.	MILLS. C. FT.		
March	..	..	..	..	..	..	..	..	+ 1,600	..
April	1,000	5,200	..	..	..	..	..	5,200	+ 1,597	+ 1,596
May	5,000	5,200	..	..	..	..	..	5,200	+ 1,596	+ 1,595
June	8,000	..	..	10,400	10,400	10,400	..	20,800	Dry.	
July	35,000	..	..	10,400	10,400	10,400	..	20,800	+ 1,593	+ 1,592
August	87,000	..	2,000	10,400	8,400	10,400	8,000	26,800	+ 1,623	+ 1,622
September	31,000	..	..	10,400	10,400	10,400	8,000	28,800	+ 1,622	+ 1,621
October	28,000	..	4,000	10,400	6,400	10,400	8,000	24,800	+ 1,623	+ 1,622
November	10,000	..	..	10,400	10,400	10,400	8,000	28,800	+ 1,616	+ 1,615
December	..	2,600	..	2,600	2,600	1,300	..	6,500	+ 1,612	+ 1,611
January	2,000	2,600	..	2,600	2,600	1,300	..	6,500	+ 1,608	+ 1,607
February	..	2,600	..	2,600	2,600	1,300	..	6,500	+ 1,604	+ 1,603
March	..	5,200	..	..	..	..	..	5,200	+ 1,601	+ 1,600

In this case the Tungabhadra reservoir is assumed to start at + 1,600, though the tables show that it can never be so low, even if two worst possible years succeeded each other. Nevertheless the reservoir meets the test successfully and finishes as high as it started. There might be scarcity for a few days in June, if Pennér irrigation started at the beginning of the month.

10. *Evaporation and absorption.*—In all the above cases evaporation and absorption have for simplicity been taken together at 1′ per month, which is of course much above the mark.

11. It will be asked why more use is not made of the Pennér by increased storage, thus diminishing the size of the Tungabhadra dam and the size of the main canal to the Pennér. There are several reasons which preclude this course. First, the Tungabhadra dam must for the purpose of the main canal be built up to + 1,600, and for storage for the irrigation of Cuddapah and protection of Bellary another 15′ is needed, bringing full supply up to + 1,615. The proposed full supply level is only + 1,630, and the extra 15′ does not add much to the cost. Second, the Pennér is an uncertain river and would often be unequal to the demands on it unless an immense reservoir capable of storing two or even three years' demands were formed, which would be much more expensive and in many ways unsatisfactory. Thirdly, the Pennér even at its best is a late river and seldom receives much water till August, sometimes not till September, occasionally not till October, and the demands during these months must be met from the Tungabhadra.

It will also be asked why another reservoir cannot be built at the junction of the Kistna and the Tungabhadra, which would be more powerful and would afford a cheaper line of waterway through Kurnool district to the Pennér. This course might be considered if there were no obligation to protect Bellary, North Kurnool, North-East Anantapur and Cuddapah. As this obligation exists, the extra expense due to the Nellore irrigation is confined to an extra 15′ of dam on the Tungabhadra and an extra width for 100 miles of main canal to the Pennér. It is calculated that these expenses amount to less than a third of the cost of a dam across the Kistna and a canal through Kurnool district.

A further question that will be asked is, why the reservoir should not be made much larger so as to be able to supply water for extension of first crop in the Kistna delta, water for the extension of second crop, water for the expansion of irrigation that is almost certain in Nellore, and water for the development of much more power than is proposed. To answer this in full detail would be a very long affair. It may be said generally here that (1) the reservoir as now proposed can assist the Kistna a good deal in extending the area of first crop, (2) that it can also if needed supply a large area of second crop in 19 years out of 20, (3) that the expansion beyond present forecasts in Nellore is likely to take at least a generation, (4) that there is not at present a patent market for more power than it is proposed to develope. But should the above possibilities develope much sooner than anticipated, the want may be met by constructing other reservoirs either above or below that now determined on.

12. *Development of power.*—A certain amount of water has to be passed down the Tungabhadra for the Kurnool canal, say 2,000 cusecs for six months and 1,000 cusecs for three months. It will be no excessive drain on the reservoir to expand this supply to 2,000 cusecs for the whole 12 months. Minimum water level in the reservoir will be + 1,500, while the bed of the river below the dam goes down to + 1,480 and it may be taken that water level below the dam will never be higher than + 1,540. There will therefore be a uniform minimum discharge of 2,000 cusecs with a potential minimum head of 60 feet, equivalent to (say) 10,000 horse-power developed. The extra water thus used will be passed on down the Kurnool-Cuddapah canal into the Pennér reservoir where it will be available for irrigation.

13. *Method of construction.*—A work so large as the Tungabhadra dam demands that practicable method of construction shall be devised and submitted beforehand, if only in order to estimate cost.

There is practically only one way to build this dam. Sluices must be built on the rock in the high portion of the river-bed on the right side at about + 1,530. These must be big enough to discharge the normal flow during most days of the year without much head. Next, at the beginning of the dry weather banks must be thrown across the deep channel above and below the site and connected on each side, so as to enclose the deep bed, which must then be filled up with masonry to a height above water level during normal flow through the sluices. The whole dam must then be continued in one piece above the sluices. During heavy floods it will always be topped until escape level + 1,600 is reached. The greatest possible speed of construction should therefore be aimed at. The mode of operations will be similar to the Assuân dam, but easier.

If the sluices are eventually to be plugged the arch will be the difficult place. If they are not plugged but are kept for use the less head on them the better. On both grounds it will be best to have them high and narrow, and a width of 7′ with a depth of 20′ will be convenient dimensions. Allowing 4′ head the velocity will be roughly 10′ per second and with 20′ above the floor the discharge per sluice will be 1,120 cusecs. Nine such sluices will discharge easily 10,000 cusecs and will occupy 243′ of the length of the dam.

Analysis of the daily discharges shows the following numbers of days on which the depth would not exceed 20′, *i.e.*, on which with that depth the sluices will discharge the whole flow in the river :—

Month.	In all years.	In a low year.	In a medium year.
January	31	31	31
February	21	28	28
March	21	31	31
April	30	30	30
May	30	31	30
June	11	25	13
July	0	19	3
August	0	2	0
September	0	14	6
October	0	12	11
November	20	27	28
December	31	31	31
Total ..	205	281	238

This does not for various reasons quite represent the number of days on which work could continue. This would in each case be less than the number shown and may be taken at 200 as a minimum. Three more sluices or a discharge of 13,500 cusecs would only give 10 more days' work in a medium year, and this would not be worth the extra expense and trouble.

These sluices, even if not eventually plugged, must remain till the dam is nearly finished and must therefore work under a great head. A special design has been made for them by Messrs. Ransomes and Rapier.

14. *Rates.*—The estimate for the dam and escape amounts to Rs. 1,06,50,000. In forecasting rates for work it is extremely fortunate that the Mári-Kanvai dam in Mysore now approaching completion furnishes an almost perfect object lesson, since the site of that work is under 100 miles from the site of the Tungabhadra dam and the circumstances are almost exactly similar, except that the Tungabhadra dam is close to a railway. This being so the rates estimated for the Tungabhádra dam, being those of Mari-Kanvai with an addition of over 10 per cent., may be taken as very liberal.

The estimates for shutters are according to quotations from Messrs. Ransomes and Rapier.

15. *Silt in reservoir.*—It is impossible to estimate with any accuracy the quantity of silt that will be deposited on the bottom of the reservoir. The percentage of silt in the river water varies enormously, and most elaborate gaugings extending over a long period of time would be needed to divine even approximately what the average percentage may be. A good many tests have been made in the Tungabhadra but the results are so conflicting as to be worth very little. It is further doubtful how much of the silt carried by the river would float in the practically still water of the reservoir, what would be the effect of the draw of the low level sluices in the dam, and what the effect of the main canal head sluices and of the flood escape sluices when the silt-deposit reaches, if it ever does reach, those levels. Speaking at a venture it may be guessed that during the flood season there is an average of 0·15 per cent. of silt in the river water. During the dry weather the silt is negligible. Speaking again at a venture it may be assumed that about 20 per cent. of the silt in the river will float in the reservoir and not be deposited. On these assumptions the amount of silt deposited in an average year would be about 540 millions of cubic feet. The total capacity of the reservoir is 120,000 millions of cubic feet, and it would therefore silt up in 220 years, if no allowance is made for the draw of the various sluices. On the whole it may be predicted that the reservoir will not at any rate silt up completely for at least 250 years, and the question may therefore be placed on one side.

16. *Main Canal; Head Sluice.*—The discharge of the main canal at head will be 12,000 cusecs. Full supply level in the canal is + 1,600, bed level + 1,580. The floors of the vents of the head sluice will therefore be at + 1,580. The shutters must work under the reservoir surface level, which may be as high as + 1,630, or a head of 50 feet. A convenient size for the vents will be 10′ span by 20′ high and there will be 12 of them. The minimum velocity required to pass 12,000 cusecs will be 5′ per second, which will be obtained with a head of 0·7, using a coefficient of 0·75 in the formula $v = c\sqrt{2gh}$. This implies a minimum surface level in the reservoir of + 1,600·7 for full discharge.

The shutters will be of Stoney's pattern.

The head sluice will be placed close to the right flank of the dam, of which it will be a part, and will be built therefore of the same materials and on the same data. The arches of the vents will be of dressed granitoid gneiss. The floors and sides will be of selected trap, which is both hard and tough and takes a fine polish.

Main canal.—In designing the main canal Kutter's formula has been used. The usual values given to N, the coefficient of roughness, in this formula, are—

Ashlar	·013
Rubble masonry	·017
Firm gravel	·020
Canals in good order	·025
„ in fair „	·030
„ in bad „	·035

Recent gaugings, however, have gone far to show that the coefficient for a canal in earth in good order is oftener ·020 and sometimes as low as ·016. In the present case it is important that the canal should not be too large and therefore a value of ·017 has been taken, which it is believed must be nearly correct for a very large canal carefully aligned and with generally a low velocity.

Certain other data have been assumed. The limiting velocity in various soils has been taken as follows:—

Nature of soil.	Mean velocity.	Side slopes.
	Feet per Second.	Ratio to 1 vertical.
Sand	2	$2\frac{1}{2}$
Light friable black soil	2	2
Stiffer black soil	3	2
Loam	$3\frac{1}{2}$	$1\frac{1}{2}$
Hard clay	4	1
Gravel	4	1
Hard gravel	6	$\frac{1}{2}$
Rock	20	...

Absorption has been assumed at 0·25 per cent. per mile in earth. This is a large allowance, as the bed nearly everywhere approaches or reaches hard and almost impermeable soil. In rock no absorption is allowed for. Evaporation is neglected.

Where possible superpassages have been considered preferable to aqueducts, insignificant drainages are allowed to enter and leave the canal, or are passed under by syphons.

The coefficient of run-off in Ryve's formula ($Q = CM^{\frac{2}{3}}$) has been taken as 600 throughout.

The line of the canal does not admit of much deviation, and there are certain fixed points, *e.g.*, the foreshore of Darόji tank, the upper side of Bellary town, from which it was not possible to diverge; while speaking generally it was essential to keep as high as possible in order to reduce the cutting through the Hagari-Pennér watershed.

The various soils, gradients, widths, etc., will be best seen in the plans (sheets Nos. 12 to 53).

Leaving the reservoir with bed level + 1,580, depth 20′, the canal runs in rock cutting round the shoulder of the hill which forms the south abutment of the dam and crosses the Kottur branch of the Southern Mahratta Railway. The country is then fairly easy and the line passes above the town of Hospet, crossing the Southern Mahratta Railway, and on into the valley of Kamalapur or the ancient Humpi, but considerably to the south of the old city, debouching at 8 miles 7 furlongs 490 feet into the subsidiary valley of Ektulamaridi. Here the ground drops very rapidly and a continuation in the same direction would follow "Gordon's line," but would be higher and even more difficult and costly. The Ektulamaridi valley will therefore be closed by a small masonry dam 87·5′ high at maximum and 1,160′ long on top. The foundations are on granite and stone will be obtained from subsequent cuttings close by. Leaving the valley in a southerly direction the line goes through heavy rock cutting for over a mile in order to attain another valley on a higher level, along which it continues without great difficulty to 13 miles. The next mile is very heavy, being through a spur of the Chikmarasu hill, almost entirely in rock cutting with a maximum of nearly 80′, and the last three furlongs of the 15th mile is through another spur almost equally heavy. It is then easy to $16\frac{1}{2}$ miles, where the Nelapur pass begins, the heaviest piece of cutting on the line, the length being $1\frac{1}{2}$ miles and the maximum depth 90′; at the end is a drop of 10′ into the Uparhalli valley, along which the canal passes without difficulty to 21 miles 2 furlongs. Besides the heavy rock cuttings the whole length so far is expensive, since though the surface is soft the subsoil very soon becomes hard, and the ground has generally such a steep sidelong slope that the section of the canal is of necessity deep.

At the end of the Uparhalli valley three courses are open: either to follow the line of least resistance and debouch on to the Bellary plain by a series of drops, thereby hopelessly losing command; or to pass round the shoulders of the range of hills in very difficult sidelong rocky ground, entailing very heavy work, much side-walling and extra distance; or to go through the hills by tunnel. The first is out of the question. Of the other two the last is the cheaper and much the better, and has been adopted. There will be two tunnels, each 14′ 3″ wide and $20\frac{1}{2}$′ deep, with a pier 50′ wide between them. This method has been adopted for several reasons, one being that a greater width might need arching, but principally because one tunnel can be driven first and will carry probably enough water for a good many years, and the other can be driven later at leisure when required, and if necessary with reconsidered dimensions.

The range of hills through which the tunnels will be driven is granitoid gneiss. In order to reduce friction the tunnels will be lined along the bottom and sides with a skin of ashlar masonry, the stone being obtained from the spoil. With this lining a coefficient in Kutter's formula (N = ·013) has been taken, the most effective condition being when the water is 20′ deep or just not touching the roof. The fall will be 19·11′ per mile and the calculated velocity is 20·16′ per second. The total length will be 9,230′, and the maximum depth overhead about 280′. The bed level at head will be + 1,542·20 and at the end + 1,508·79. The water will debouch into a wide cistern cut out of the rock, in order to reduce the disturbance due to the high velocity.

From this point it is possible to bring the surface of the water out of soil and so reduce cutting and keep in softer stuff. The canal now runs south along the foreshore of Darόji tank in easy soil, but at 27 miles 1 furlong 480 feet meets the Narihalla, the feeder of the tank, a stream with sometimes a considerable discharge, the catchment being 190 square miles. This stream crosses over the canal by a superpassage of 6 vents of 20′ span, calculated to allow for a maximum flood of 20,000 cusecs. The bed is raised 4′ over the canal and drops back on the down-stream side. Although the canal crosses the drainage of the country throughout, it is never far from the foot of the hills and the above is far the largest stream encountered until the Chinna Hagari is reached.

Continuing, the canal again crosses the Southern Mahratta Railway and then curves round to the north-east through easy country to the shoulder of an outlying spur of the Sándúr range, crossed in a short rock cutting close to Darόji station, which will have to be moved slightly northwards. From this point the country is easy as far as 53 miles, the only important points being two crossings of the railway and a slight diversion and raising of a short length of the line. At the 53rd mile the line passes south and west of Bellary town. The bed level here is + 1,503·50 which commands the Brucepett or principal native quarter, but does not command the whole of the cantonment and its ancillary native quarter of Cowl Bazaar. The drinking water-supply of the latter will therefore have to be pumped up a few feet.

In proceeding, three lines through the town are possible. By far the cheapest and best is that followed on the plan. It entails the destruction of certain native infantry lines, but any other course is much more destructive. The Military authorities having had the matter placed fully before them approve of the line chosen, and an approximate sum for compensation has been entered in the estimates. In this length there is a rock cutting with a maximum of 22′ which cannot be avoided.

Continuing in contour, the canal crosses the Bellary-Bangalore road at 56 miles 3 furlongs 430 feet.

After crossing the Bangalore road the main canal runs generally on contour through country showing no marked features till it meets the Chinna Hagari at mile 75 and afterwards the Pedda Hagari at mile 91. It was first proposed to cross these two rivers below their junction by means of a dam and reservoir, but this was found to entail a very high, long, and expensive dam with foundations at considerable depth below the bed, together with great waste of water, so this idea was abandoned. The Chinna Hagari is therefore crossed by a regulator of 12 spans of 80′, with shutters 12′ deep. The catchment is 960 square miles, and the maximum flood has been taken at 70,000 cusecs, which will pass through the regulator with a depth of 8′. This maximum is probably above the mark, but the error is on the side of safety. In order to save distance the canal is dropped into the Chinna Hagari over a fall of 8′, but it is quite likely that some economy can be attained by omitting the fall and crossing this river, and consequently the Pedda Hagari also, higher up.

Between the Chinna and Pedda Hagari the country is ordinary rolling black cotton. Enquiries were made with a view to crossing the Pedda Hagari by a dam and reservoir, but the same objections were found to exist as in the case of the dam mentioned in the last para. This idea therefore was likewise abandoned, and the Pedda Hagari is crossed by a regulator of 17 spans of 80′ with shutters 12′ deep. The catchment is 4,270 square miles, and the maximum flood has been calculated at 130,000 cusecs. Considering the nature of the basin and the existence of a powerful flood-moderator 90 miles higher up in the shape of the Marikanvai dam, this is doubtless an over-estimate, but the depth of the canal necessitates 12′ shutters and it was considered wiser not to narrow the natural bed of the river.

These two regulators are the largest in the project. In both cases leakage under them would be a loss of water, and provision has therefore been made for sheet-piling on the up-stream side of both. Clay is found at no great distance beneath the river-beds. These beds are all sand, which is coarse and probably does not rise much off the bed but is doubtless swept along during floods. The canal accordingly takes off from each, over a 3′ weir. It will perhaps be found advisable to drop the canal into the Pedda Hagari over a similar weir.

The sheet-piling above mentioned will catch the subsoil flow in the Pedda Hagari. Slight freshes also will serve to increase the supply of the main canal to be passed to the Penner, and consequently the masonry works in the canal from the Pedda Hagari onwards have been designed to carry 400 cusecs more than reaches the Pedda Hagari crossing, bringing the net discharge into the Penner to 6,000 cusecs. The canal itself has not been estimated for the increase, but berms admit of future widening.

The canal passes through ordinary country after leaving the Hagari to mile 119, where it is decided after numerous surveys to pierce the Hagari-Penner water-shed. The cutting involved is 4 miles long with a maximum depth of 69′. The top soil is light but below is rock, and a velocity of 10′ a second is allowed, thus reducing the bed-width to 47′. A greater velocity would have increased the length uneconomically. The cutting is regulated at head by a masonry work of 3 spans of 40′.

From the end of the water-shed cutting the water finds its own way to the Penner, with a fall of some 245′ in about 3 miles, a valuable source of power in the future.

The discharge of the main canal at head will be 12,000 cusecs. Of this it is estimated that 2,600 cusecs will be lost by absorption *en route*. The distributaries of Bellary West Block will take 1,200 cusecs, and the Adoni-Kurnool canal 2,600 cusecs, and the remainder, 5,600 cusecs, will be delivered into the Penner for use in Anantapur, Cuddapah and Nellore districts.

17. *The Penner.*—The Tungabhadra water, now mingled with Penner water, travels down the bed of the Penner for about 33 miles till it reaches Ullikal, 16 miles above Tadpatri, where a regulator will be built. At this point a canal takes off on the right bank to command Tadpatri, Pulivendla, Muddanur, and Cuddapah taluks. The rest of the water continues flowing in the Penner to Mailavaram, just below the Gandikota gorge and 3 miles above Jammalamadugu, where a regulator will be built to enable a canal to take off for the irrigation and protection of Jammalamadugu and Proddatur taluks. The remainder of the Tungabhadra water passes on for 79 miles to the boundary of the Nellore district, close to which, and hard by the temple of Somesila in a gorge of the hills, a dam will be built and a reservoir formed. From this reservoir two large canals take off, one on each side of the river, for the irrigation of north and south Nellore.

18. *Somesvaram dam.*—This dam is necessary in order to store water and to raise it to command sufficient areas north and south of the Penner in Nellore district.

The river runs here through a narrow clean-cut gorge half a mile long and 1,200 feet wide with high hills on each side. The range on the south side is rather wider than that on the north side, and the river begins to widen out sooner on the latter side than the former. The hills are of very hard quartzite rock; see sheet No. 342. Several methods of building a dam are possible. *First*, a dam may be built across the narrow part of the gorge and flood water allowed to pass over it as over a weir. This is perhaps the cheapest dam, but it has been rejected, because of the bad effect of the vibration of water falling incessantly on to the bed of the river immediately below the dam, and because of the trouble and expense of taking off canals along the hard high cliffs on each side. *Second*, a dam may be built on the skew or on a curve, so as to be long enough to contain a sufficient number of vents to pass the maximum flood. This plan is the dearest and the most complicated. *Third*, a dam may be built where the gorge begins to widen out, which means a high level escape can be obtained on the left bank. The latter course combines the greatest number of advantages and has been selected.

19. *Foundations.*—The river-bed is sandy, the banks are of precipitous quartzite rock. This rock is excellent for a foundation and for the construction of the dam (*see* Geological Report, page 54). Borings have been taken near the line of the dam across the river, and the section on sheet No. 345 shows the result. Other borings were taken higher upstream to see whether the hard rock did not occur at a higher level, but the result was the same. The hard rock at the bottom of the bore-hole has been taken out in core by a diamond drill for a depth of 12′ and it may be accepted that nothing soft exists underneath.

20. *Disposal of floods.*—The catchment basin of the Penner is 18,710 square miles, the general rainfall being moderate but with occasional cyclonic downpours. General Mullins in his Irrigation Manual gives the maximum flood discharge as 550,000 cusecs, but no details, ascribing this flood however to the breaching of numerous tanks combined with cyclonic rainfall. The maximum recorded flood is that of November 30, 1882, which is said to have been gauged at the Nellore anicut, but there is considerable doubt as to the reliability of the gaugings. Taking the readings as they stand the result is 447,000 cusecs. Mr. Stoney in a paper read before the Institute of Civil Engineers (Vol. CXXXIV) gives maximum floods of the Penner and its three great affluents, the Cheyar, the Papaghani and the Chitravati, as aggregating

700,000 cusecs in October 1874. This was, however, spread over three days, 24th, 25th and 26th of the month and doubtless did not occur simultaneously in all the rivers. The same flood was gauged at Nellore anicut and amounted to less than that of 1882. It was probably in General Mullins' mind, as it was due to a copious south-west monsoon which filled all tanks, followed by an abnormal north-east monsoon with cyclonic rainfall and the sudden addition of the waters of burst tanks to the already swollen river. We may then on the whole accept 500,000 cusecs as the maximum flood comparable to a co-efficient of 710 in the formula $Q = CM^{\frac{3}{4}}$.

An escape 1,064 feet long on the left bank will discharge 350,000 cusecs with a depth of 25 feet. This will be the length of escape, and the crest level, partly cut down and partly built up slightly, has been fixed at + 285, the foundation being all hard quartzite. The crest of the dam will be at + 299, and the balance of the maximum flood, viz., 150,000 cusecs, will pass over the dam with a depth of 11′. Should the maximum calculated flood be exceeded the result will be only a slight increase in the depth of water on the escape and on the crest of the dam. The crest of the dam being 14′ above escape, the dam will not be topped until the flood discharge exceeds 150,000 cusecs. The subjoined table shows that this will rarely happen and for very short periods.

Number.	Year.	Time of rise to 150,000 cusecs.	Time of maximum rise.	Time of fall to 150,000 cusecs.	Upper gauge readings.	Lower gauge readings.	Difference of water levels.	Depth of tail water over crest.	Discharge in cubic feet per second at M.F.L.	Duration of flood above 150,000 cusecs. D. H. MTS.
1 (*a*)	1874	11th Sept., 1-30 P.M.	11th Sept., 6 P.M.	12th Sept., 1 A.M.	18′ 3′	11′ 10″	6′ ″	2′ 10″	157,424	0 11 30
(*b*)	1874	16th Sept., 4-30 A.M.	16th Sept., 4 P.M.	16th Sept., 11-15 P.M.	19′ 3″	12′ 3″	7′ 0″	3′ 3″	183,631	0 13 45
(*c*)	1874	17th Sept., 12 A.M.	18th Sept., 6 A.M.	18th Sept., 8-15 A.M.	18′ 6″	12′ 0″	6′ 6″	3 0″	163,851	0 20 15
(*d*)	1874	22nd Sept., 4 A.M.	22nd Sept., 6 A.M.	22nd Sept., 8 A.M.	18′ 0″	11′ 6″	6′ 6″	2′ 6″	150,953	0 4 0
(*e*)	1874	23rd Sept., 2-15 P.M.	23rd Sept., 6 P.M.	23rd Sept., 12-45 P.M.	18′ 6″	12′ 0″	6′ 6″	3′ 0″	163,851	0 10 30
(*f*)	1874	24th Sept., 10 P.M.	25th Sept., 5 P.M.	26th Sept., 9-30 A.M.	18′ 7″	11′ 7″	7′ 0″	2′ 7″	165,784	1 11 30
(*g*)	1874	24th Oct., 3 P.M.	26th Oct., 6 P.M.	29th Oct., 7-45 A.M.	27′ 4½″	22′ 4½″	5′ 0″	13′ 4½″	360,946	4 16 45
2	1878	6th Oct., 9-30 A.M.	6th Oct., 9 P.M.	7th Oct., 1-30 A.M.	18′ 0′	10 0	8 0″	1 0	189,441	0 16 0
3	1882	30th Nov., 9 A.M.	30th Nov., 11-45 A.M.	2nd Dec., 8-45 A.M.	28 3	21 3	7 0	12 3	550,000	1 23 45
4	1883	17th Oct., 4 P.M.	18th Oct. 5-45 A.M.	18th Oct., 6 P.M.	19 0	12 1	6 9	3 1	228,566	1 2 0
5 (*a*)	1884	10th Nov., 9-30 A.M.	10th Nov., 2 P.M.	10th Nov., 8 P.M.	17 6	10 7	6 9	1 7	180,495	0 10 30
(*b*)	1884	22nd Nov., 7-45 P.M.	23rd Nov., 3 A.M.	23rd Nov., 12 A.M.	18 4	11 8	6 6	2 8	208,266	0 17 15
6	1886	13th Oct., 2 A.M.	15th Oct., 9 P.M.	17th Oct., 8 A.M.	18 6	13 9	4 7	4 9	207,491	3 6 0
7	1887	8th Sept., 3-30 P.M.	8th Sept., 11 P.M.	9th Sept., 7-30 A.M.	18 0	12 1	5 9	3 1	194,978	0 16 0
8	1889	17th Oct., 7 A.M.	17th Oct. 11-30 P.M.	19th Oct., 8 P.M.	24 0	17 0	7 0	8 0	401,415	2 13 0
9	1892	29th Oct., 6-45 P.M.	30th Oct., 12 P.M.	31st Oct., 6-30 P.M.	19 0	13 0	6 0	4 0	227,084	1 23 45
10	1893	7th Nov., 12-45 P.M.	7th Nov., 6 P.M.	8th Nov., 7-15 A.M.	19 2	12 7	6 5	3 7	234,951	0 19 0
11	1895	27th Oct. 4 P.M.	27th Oct., 12 P.M.	28th Oct., 7-15 A.M.	18 0	12 4	5 6	3 4	194,450	0 15 15

21. *Storage.*—The sandy bed of the river is at about + 220. The level of the floor of the lowest head sluice, that for the north canal, is + 280, and between those levels the water stored will be idle. It amounts to about 12,000 millions cubic feet, and will never be drawn off. Between + 280 and + 285, the escape level, the storage is about 10,000 millions, and in nearly all years this will be filled up by the Pennér, though late in the season. Until that time a major part of the water required for irrigation must be supplied by the Tungabhadra.

In the course of time it will probably be found that the Nellore irrigation will largely extend, and that use can be found for more storage, of which the Pennér is in most years highly capable. In such a case the storage can be increased by raising the escape and allowing a greater proportion of high floods to flow over the dam; or both escape and dam may be raised; or the escape may be lowered and sluices substituted; or subsidiary reservoirs may be made either above or below, there being several suitable sites. An elaborate enquiry into this question does not need to be attempted at present.

22. *Submersion.*—The area submerged at + 285, full supply level, will be about 20 square miles, but it is necessary to allow for the total submergence at maximum flood level, + 310. This will amount to about 32 square miles. There are a few small villages and one, Obalum, of some size, and there is also a certain amount of cultivation, but a great part of the area is sandy waste, or steep stony uncultivated ground, or poor jungle.

23. *Silting.*—There is a good deal of silt in suspension in the Pennér during freshes, and plenty of sand is also swept along the bottom. To a certain extent both these will be deposited in the reservoir. But the cross section of the lake is not generally large and there will be an appreciable velocity, which will carry on a great deal of silt. Near the dam, in the gorge, the velocity will be high, and there will be an undoubted scour. On the whole and in view of the ease with which the storage can be increased, it is not considered that this is a question which need be faced until, if ever, it becomes serious.

24. *Design of dam.*—The dam will be of the same length on top as the width of the river, viz., 1,200 feet. The sections show that there is a depth first of about 30′ of sand in the river bed. Underlying this is a bed, triangular in cross section, of a silicious clay, pebbles, conglomerate and soft white rock, the thickness being little or nothing near the banks but increasing to some 60 feet at the centre. Below this, hard purple quartzite is found everywhere. The foundation of the dam will be let 6′ into the quartzite and built in hard to the rock. From the lowest quartzite surface level to the crest of the dam will be 170 feet and for this maximum height the dam is designed. Water 11′ deep is liable to flow over the top, and though at such a time there will be a considerable depth of water below the dam it has been designed for the whole pressure. It is assumed that less than 3′ of water falling on the masonry of the down-stream face will not damage it, and the latter has been designed so that a greater depth will fall clear at average bed level. The limiting intensity of pressure has been taken at 10 tons per square foot, and the weight of masonry 140 lbs. per cubic foot.

25. *Materials.*—The principal material of the dam will be uncoursed rubble masonry, the stone being quartzite, of which the hills all round are composed. The upstream and down-stream faces will be built of uncoursed gneissic granite rubble masonry, this stone being available within a distance of 10 miles. The crest will be of dressed granite. Kunkur lime is found in the vicinity, and the best of sand is in large quantities in the river bed. Surki can be burnt close by.

The escape will also be built up of uncoursed quartzite masonry with a facing of granite; but the crest will be of dressed trap, a very hard tough stone capable of a high polish, which is found within 12 miles.

26. *Method of construction.*—This dam, though confined within a narrow gorge with no chance of diverting the river, should not be a difficult work to build. The Pennér runs very dry during the dry weather and there is a long period, practically from February to September, when the discharge can easily be carried in a small flume. There will be a depth of some 30′ of sand to excavate, which can be supported if necessary by wells or piles or sand bags or stone revetment. Below this is the silicious clay, running down in places for 60′. This will no doubt take time to excavate but will stand for some time without support. With suitable arrangements it should be feasible to get in the foundations in a single working season, and therefore the work will be ordinary.

27. *Distribution.*—The following table gives the irrigation and protection required in each block and the discharge of each principal canal :—

Block.	——	Irrigation, acres.	Protection, acres.	Discharge at head cusecs.
Bellary West	Main canal	97,200	271,000	12,000
Bellary East	Adoni and Kurnool canal	198,700	529,000	2,600
Tadpatri	Tadpatri canal	38,500	..	1,625
Pulivendla	Pulivendla canal	19,500	75,000	1,236
Muddanur	Muddanur canal	26,900	75,000	816
Cuddapah	Cuddapah canal	32,200	..	322
Jammalamadugu	Jammalamadugu canal	43,000	50,000	580
Nellore North	Nellore North canal	150,000	..	3,000
Nellore South	Nellore South canal	200,000	..	3,000
	Total ..	806,000	1,000,000	..

The main canal is not to be considered as the aggregate of all the others. The Tadpatri canal also serves Pulivendla, Muddanur and Cuddapah, the Pulivendla canal serves also Muddanur and Cuddapah, and the Muddanur canal carries water for Cuddapah as well as for itself.

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28. *Bellary West block.*—This comprises all Bellary between the canal, and the Hagari river, and is watered direct from the main canal. The areas under the branches are all small, except under Nos. 4 and 7 which irrigate respectively 34,897 and 12,592 acres. All the branches of any importance have been surveyed in detail, and make a good average from which to deduce the probable price of others.

29. *Bellary East block.*—The Adóni-Kurnool canal takes off from the main canal at 116 miles 2 furlongs 400 feet by a head sluice with two vents of 40′ × 12′. The discharge will be 2,600 cusecs for an expected irrigation of 198,700 acres. The canal being a long one absorption is specially allowed for. Owing to the character of the soil a large section and low velocity are inevitable almost throughout. The depth is 12′. A berm of 8′ has been allowed on each side for future widening. In calculating the section a value of ·018 has been given to N in Kutter's formula. Cross drainages are disposed of in the same manner as in the main canal, and due provision is made for bridges.

It will be possible if considered safe to cheapen this canal by running it more out of soil.

There are no special features in the canal till Guntakal station is approached near mile 37½. This station, an important junction of the Madras Railway, North-West line, the Southern Mahratta Bezwada-Guntakal line, the Southern Mahratta Bangalore-Guntakal line, and the Southern Mahratta Gadag-Guntakal line, lies exactly on the Pennér-Hagari watershed. The canal has to drop 5′ to pass under the rails, full supply level being 2½′ below rail level. It passes unavoidably across the station, but has been arranged in the least objectionable manner to cross only one metre-gauge track of the Southern Mahratta Railway and one broad-gauge track of the Madras Railway; just before the station the Gooty branch takes-off.

Continuing, the canal runs in contour to the Molagavalli watershed which must be crossed to reach Adóni and the Hindri basin. This is a very heavy cutting, 25′ wide with a maximum depth of 92′, and 7 miles long. The top soil is black cotton, with decayed crystalline rock below. The canal then continues through difficult country to 84 miles. From this point the canal divides. One branch goes past Adóni to the Tungabhadra, commanding the country between the Tungabhadra and the Hagari. The most important branch of 740 cusecs crosses into the Hindri basin and after irrigating various areas in Pattikonda taluk tails into the projected Gazuladinne reservoir. Continuations of the channels already designed under the Gazuladinne project enable this branch to irrigate a further considerable area towards Kurnool.

30. *Tadpatri block.*—At Ullikall on the Pennér a regulator will be built of 19 spans of 80 feet. The shutters will be 9′ high and the depth of water in the off-take canal 8′. The shutters will be of Stoney's pattern. The catchment area is 4,230 square miles, and the maximum flood has been taken at 150,000 cusecs, with a coefficient of 570 in Ryves' formula $Q = C M^{\frac{2}{3}}$. This flood will flow through the regulator at a depth of 14 feet, and provision has accordingly been made for raising the shutters this height. The foundation here, and in the case of all large rivers in Cuddapah, is sand. The design for the shutters is by Messrs. Ransomes and Rapier. The counterweight travels down the inclined back of the pier, being protected from submergence by a wooden casing.

At this point a canal takes off and passes through the Tadpatri taluk to the Chitravati. It will not only command Tadpatri taluk, but will also carry water for the Pulivendla, Muddanur and Cuddapah blocks.

The head sluice consists of 7 vents 20′ × 4′ and is designed to pass 1,625 cusecs with a head of 0·34′. In the Tadpatri block there will be only 38,500 acres of irrigation. The rest of the water will drop into the Chitravati.

The Tadpatri canal will be 36 miles long, with a depth of 8′ and a fall of $\frac{1}{10,000}$. It will be generally in about 5′ cutting, so that the earthwork balances the banks. At the beginning of the 6th mile the canal passes through the Peddapappur hill by a tunnel 900 feet long. The section proposed is 18½′ × 8′, and the fall $\frac{1}{1,000}$, which gives a velocity of about 11′. The hill is composed of good compact limestone and neither lining nor arching is required.

At 30¾ miles another tunnel 1,020′ long is needed to pass through the Chinnagarugu hill. This will be in shale and will need lining and arching. The section will be 11½′ × 8′ and the fall $\frac{1}{500}$. The required discharge here is 1,236 cusecs, which is obtained with a velocity of 13′ per second. Below this the canal will run 7′ deep, and reaches the Chitravati above the ruined village of Obalapuram.

The only cross drainage work of importance is the Idula Vanka at 9 miles 330′, with a catchment of 61·5 square miles and a maximum flood discharge of 7,700 cusecs. This is discharged under the canal by 22 vents of 10′ span to carry 7′ of water.

Due provision has been made for bridges.

Those branches and distributaries only that are of importance have been surveyed and designed in detail. The country has been contoured by means of numerous cross sections and the less important branches, etc., have been approximated from these, and lump sums allowed for them. The natural fall of the country is steep and a good many drops will be needed.

The following materials are available and will be used, viz., granitoid gneiss, trap, and lime kankar.

31. *Pulivendla block.*—The regulator on the Chitravati will be built just above the village of Kodamurti and will be of 23 spans of 60′ with shutters 8′ high. The catchment area is 2,200 square miles and the maximum flood has been calculated at 101,400 cusecs, with a coefficient of 600 in the formula $Q = C\ M^{\frac{3}{4}}$. This flood will pass through the regulator with a depth of 9·5′, and the piers and shutters have been designed accordingly. The type is similar to that at Ullikall.

At this point the canal takes off for the Pulivendla, Muddanur and Cuddapah blocks.

The head sluice will have 6 vents of 20′ × $3\frac{1}{2}$′ and will discharge 1,236 cusecs with a head of 0·33′. The total area to be served is 78,000 wet and garden lands and 150,000 acres protection of dry crops.

The main canal is 12 miles 2,520′ to the point where the Muddanur canal diverges; so far the depth will be 7′ and the fall $\frac{1}{10,000}$. The canal then continues with a fall of $\frac{1}{7,500}$ to 13 miles, where it divides into the Pulivendla No. 1 and No. 2 canals, which run on each side of the Mogameru Vanka. The main canal crosses the Chitravati-Papaghni watershed with a cutting of 10·56′ maximum.

Pulivendla No. 1 canal will be $38\frac{1}{4}$ miles long and will irrigate 15,800 acres of wet and garden lands, and protect 53,200 acres of dry land. The fall will be $\frac{1}{5,000}$ and the depth 5′ at head and 1·75′ at end.

No. 2 canal will be $22\frac{3}{4}$ miles long and will irrigate 2,400 acres of wet and garden lands and protect 14,000 acres of dry land. Fall $\frac{1}{5,000}$, depth 3·5′ at head and 2·5′ at end.

32. *Muddanur Block.*—As already stated the canal carrying water for this block and the Cuddapah block takes off at $12\frac{1}{2}$ miles from the Pulivendla main canal though it is not unlikely that it may be found more economical to carry the Cuddapah block water *via* Pulivendla. The required discharge is 816 cusecs, of which 322 cusecs is for Cuddapah taluk. The length will be $53\frac{3}{4}$ miles, and the irrigation in this block will be 26,900 acres, with protection of 75,000 acres of dry land.

From 8 to $21\frac{1}{2}$ miles the canal skirts the hills, crossing the nose of the range near Kondapuram by a tunnel 3,160 feet long in the 11th mile. The material is shale, so the tunnel will be lined and arched. The section will be $9\frac{1}{2}$′ by 7′ and the fall $\frac{1}{550}$, the velocity working out to 12·25′. In the case of this and all tunnels throughout the project, a cistern will be provided at the end to allow the stream to settle down and continue at a reduced velocity. At $19\frac{1}{2}$ miles, after passing Mangapatnam, the canal crosses the watershed with a maximum cutting of 44·74′, the fall here being $\frac{1}{2,500}$, velocity 6·5′.

From $21\frac{1}{2}$ to $26\frac{1}{2}$ miles the canal falls $81\frac{1}{2}$′ by a series of drops. Thence it runs in contour with a fall of $\frac{1}{7,500}$ and then $\frac{1}{5,000}$, depth being 7′, 6′, and 5′. Eventually it falls into the Mogameru Vanka near Mailacheruvu village.

There are no cross drainages of importance. Adequate provision has been made for bridges.

The same procedure as in the case of the Tadpatri canal has been adopted with regard to branches and distributaries. Branches Nos. 2 and 6, 23 miles and $16\frac{3}{4}$ miles long, respectively, have been estimated in detail.

The following materials are available and will be used, viz., trap, sandstone, Cuddapah slab, and kankar lime.

33. *Cuddapah block.*—The water brought by the Muddanur canal and dropped into the Mogameru flows thence into the Papaghni, when it will be caught by a regulator below Tummalur, and turned into the Cuddapah canal. The shutters will be 6′ high, the depth of water in the canal being 5′. There will be 34 spans of 60′ and the general arrangement will be similar to the other regulators. The catchment area is 2,450 square miles, the maximum run-off from which is calculated at 109,200 cusecs, with a coefficient of 600 in the usual formula. This represents a depth of 8·5′ on the regulator which has been designed accordingly.

The head sluice consists of 3 vents of 20′ × $2\frac{1}{4}$′ and will pass the required discharge of 322 cusecs with a head of 0·2′.

The canal will be $18\frac{1}{2}$ miles long, and will irrigate 32,200 acres of wet and garden land. The fall will be $\frac{1}{6,000}$ throughout, the depth diminishing from 5′ to $2\frac{1}{2}$′. In the 2nd mile there is a short heavy cutting, maximum 19·32′. It finishes in the Chintakommadinne tank.

The only cross drainage of importance is the Jinkala Vanka at 6 miles 4,820 feet. The catchment area is 51 square miles and the calculated maximum flood discharge 6,685 cusecs, which is passed under an acqueduct by 25 vents of 10′ span, $3\frac{1}{4}$′ to springing, with a velocity of 5′ per second.

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Due provision has been made for bridges.

In this block nearly all the branches and distributaries have been surveyed, designed, and estimated in detail, so as to form a fair example to check the accuracy of the approximations in the case of the other blocks, where most of the distributaries have not been worked out in detail.

The following materials are available and will be used, viz., Cuddapah slab, and kankar lime.

34. *Jammalamadugu block.*—For this block a regulator will be constructed on the Pennér near Mailaveram 3 miles above Jammalamadugu, and just below the well-known Gandikota gorge. The regulator will be of 19 spans of 60′, with shutters 7′ high. The catchment area is 7,310 square miles and calculated maximum flood 200,000 cusecs with a co-efficient of 530. This will mean a depth of 19′ in the river and the piers and shutters have been designed accordingly.

The head sluice will consist of 4 vents 20′ by 3′ and will pass the required discharge of 580 cusecs with a head of 0·23′.

Nossam canal.—This canal will be $20\frac{3}{4}$ miles long and will irrigate 43,000 acres of wet and garden land and protect 50,000 acres of dry land. It will run 6′ deep with a fall of $\frac{1}{7,500}$. At 2 miles the Proddatur canal takes off, and from this point the Nossam canal is of moderate size, and needs no detailed description, the only points worthy of notice being two stretches of embankment in the 13th and 15th miles, the latter being 14′ maximum.

The Proddatur canal will be 20 miles long and will irrigate 33,600 acres of wet and garden lands and protect 50,000 acres of dry land. It will run 6′ deep at head with a fall of $\frac{1}{7,500}$ and reduce gradually to $1\frac{1}{2}$′ deep with a fall of $\frac{1}{2,500}$. It encounters no difficulty of importance.

The only serious cross drainage work in this block is the Alugu vagu at 8 miles 4,260 feet of the Nossam canal. This drain has a catchment of 146 square miles and a maximum flood discharge of 12,600 cusecs, which is passed under the canal by a work of 25 spans of 10′, with a depth of water of 10′. The bed of the Vagu is rocky.

Bridges have been provided where necessary.

The branches and distributaries have been estimated in the same way as for Tadpatri, etc., a few being taken out in detail as a guide.

The following materials are available and will be used, viz., sandstone, Cuddapah slab, and kankar lime.

In all cross drainages in the Tadpatri, Pulivendla, Muddanur, Cuddapah, and Nossam canals, the maximum flood discharge has been calculated by Dickens' formula $Q = CM^{\frac{3}{4}}$ with a co-efficient of 350. In the case of the Proddatur canal, which runs through flat country, the co-efficient has been reduced to 250.

35. The sites of all the regulators have been very carefully chosen. They are all at spots where the rivers cannot well alter their courses, and where the deep channel runs close to the position of the head sluices. All have a rock abutment at the head sluice end. The size of gates proposed is larger than hitherto used in India, but Messrs. Ransomes and Rapier are prepared to build them, and have built them elsewhere. *Cæteris paribus* it is assumed that the bigger the span the better, as making less change in the normal régime of the river, offering less obstruction, and minimising the chance of objects lodging in the ventway. The works have been shown in the plans and estimates as founded on wells but this should not be necessary in practice.

36. *Nellore North block—Head sluice.*—The floor of the head sluice will be at + 260, the depth 10′. It will be built at the extreme left of the escape, of quartzite rubble masonry with a facing of granetoid gneiss. The arches of the vents will be of granite, and the floors and side walls of the same. The discharge provided for is 3,000 cusecs, which will be passed by four vents of 10′ span with a head of 4·71′. Generally speaking, the head on the shutters will be less than 25′, but in the case of a heavy flood, it may be needful to manipulate them under greater heads, and Stoney's pattern will therefore be employed.

37. *Nellore North canal.*—This canal will carry water for the acreage allotted to it in the table on page 38, and also for the Sangam anicut system. The latter is at present fed direct from the river, but the loss by absorption, evaporation, and leakage under the Sangam anicut must be very great. The Sangam canals will be retained, and also the reservoirs for the present, the latter being filled from the river during freshes.

The first part of the canal runs through talus from the hills, very permeable stuff, and will also have to be protected from the flood water spill. The talus must be lined and though there will be a flood bank it is considered safer to arch the canal. The first 1,000′ will therefore be in cut and cover, composed of four tunnels 10′ wide. Three are enough, but another is allowed for accidents and for future expansion.

Beyond the tunnels the canal runs in contour, a berm of 20′ being allowed for expansion. At 8¼ miles it crosses the Kathumannar, a stream with a drainage area of 85 square miles and a maximum calculated discharge of 11,640 cusecs. The canal bed here drops 1·0′ and the drain goes over it in a superpassage 500′ wide between wings and 9′ deep. All superpassages are, for safety's sake, designed of the full width of the river-bed. At 11½ miles the first Gauraveram ridge is cut through with a maximum depth of 37′, and at 15 miles the second Gauraveram ridge with a maximum depth of 38′. The canal then continues on contour, passing under the two branches of the Baggeru river, the bed being dropped 1·0′ in each case. The first branch has a drainage area of 184 square miles, and the width of superpassage allowed is 850′. The second 76 square miles, and the width of superpassage 770′. Both these works will be founded on rock. At 48 miles is the Birapera river, width of superpassage 300′, with a 1·0′ drop to the canal. These drainages are so large that the method adopted for crossing them is considered the best, in spite of some loss of command.

At 59¾ miles the main branch takes off, running on the watershed between the Pennér and Upputeru and terminates in the supply channel to Allur tank.

The rest of the canal runs along the watershed between the Manneru and the Upputeru.

The principal branches have been surveyed in detail, but for the smaller branches—some of them very minute—lump sums are allowed.

38. *Nellore South block—Head sluice.*—The floor of the head sluice will be at + 262, and full supply level + 272, the general arrangement being the same as for the North canal. The discharge provided for is 3,000 cusecs, which will be passed by four vents 10′ span. The sluice will be located at the extreme right flank of the dam.

39. *Nellore South canal.*—This canal, besides its own area, will carry water for the existing irrigation under the Nellore anicut, the reasons for this course being similar to those mentioned in the case of the North canal and the Sangam anicut.

The first portion of about a mile has to be cut out of the side of the hill in rock and will have a bed width of 50′, depth 10′, fall 2′ per mile. Three small ravines are crossed by building walls across them. The stone from the cutting will be used in the dam. On emerging into better country the fall is reduced to 9″ per mile.

Both this and the North canal are calculated with a value of 0·020 for N. in Kutter's formula in ordinary soil.

After leaving the hills the canal runs practically in contour, through the first part of the country being difficult various lines have had to be surveyed. At 26½ miles it cuts through the watershed between the Pennér and Kandleru with a maximum of 39′, and at 41 miles the Rapur watershed between the Kandleru and Venkatagiri rivers. The latter involves a maximum cutting of 80′, but is as cheap as following the contour and shorter. At mile 73 there is a short cut to avoid the Raja of Venkatagiri's private grounds. The canal eventually tails into the Swarnamukhi river, beyond which it is not thought advisable to extend it at present.

This canal runs much closer to the hills than the North canal and the drainages to be crossed are far less serious. The first of importance is the Kandleru river at mile 35½, the catchment being 53⅜ square miles. The canal is dropped 1·0′ and passes under this. At mile 69½ the Venkatagiri river, with a catchment of 20 square miles, is passed over the canal in the same manner.

The principal branches have been surveyed in detail.

Due provision for bridges has been made in both north and south blocks.

40. *Power.*—There are two points in the system where water-power will be running to waste and can easily be transformed.

The first point is at the Tungabhadra Dam, where the fall of the water passed down the river will never be less than 60 feet. A minimum of 2,000 cusecs for six months and 1,000 cusecs for three more months will normally be passed down for the Kurnool-Cuddapah canal, and it will be no great strain on the reservoir to extend this quantity to 2,000 cusecs all the year round, especially as the excess not needed for irrigation can be sent through the Kurnool-Cuddapah canal into the Someswaram reservoir on the Pennér and there stored for the irrigation in Nellore. In calculating the working of the reservoir these quantities have been allowed for. There will thus be a minimum of some 10,000 horse-power always available.

There is a market for quite 5,000 horse-power for factories, presses, etc., at Gadag and Hubli, distant about 50 miles and 80 miles, respectively, from the dam. Enquiries have been set on foot to ascertain the prices of steam-power as now used at these places, but the answers are vague and incomplete, and the enquiry should be prosecuted on the spot. Certain firms of high standing in Europe and America have been furnished with details and asked to prepare a scheme and estimates for the development and transmission, but all their answers have not been received in time for inclusion in this report. The matter ought to receive closer investigation, and should not be relegated to a time when the project shall have been sanctioned, since it will be necessary to adapt a portion of the Tungabhadra Dam for the use of turbines. The cheapest estimates so

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far received are from Messrs. Escher Wyss & Co. for turbines and from Messrs. Brown Boveri & Co. for electric plant. Compounding these estimates and providing for parts not included, we get the following result:—

	£
Turbines f.o.b.	20,324
Freight to Mormugao	2,500
Carriage to site	1,000
Erection and fitting	3,000
Electric plant and transmission line	50,465
Freight to Mormugao	3,500
Carriage to site	2,000
Erection and fitting	5,000
3,500 posts	5,000
Sundries	17,211
Establishment and other percentages	30,000
Total for 8,000 horse-power ...	140,000

or about £18 per horse-power.

The interest on £18 at 5 per cent is less than £1; allowing £1 per horse-power for depreciation and £1 for working expenses, it would seem that any returns over £3 or Rs. 45 per horse-power would be clear profit, assuming that the total horse-power could be sold. The above figures should be very liberal and it is at any rate clear that the scheme is one of promise and would be a valuable factor in the progress of the country around the head works.

The second point where power is available is where the main canal falls into the Pennér, with a drop of 245′. The discharge of the main canal at this point is 5,600 cusecs, so that there will be an enormous quantity of power running to waste. But for 3 months in the year the main canal discharge will be very small. Also there is no obvious demand for power in the vicinity. For these reasons this matter has not been further investigated.

It may not be out of place in this connection to draw attention to the possibility of treating iron ores by one of the several electro-thermic processes which are either already commercially feasible or on the verge of becoming so. The Sandur hematite deposits are near, and are according to the geologists of very unusual richness.

41. *Cost.*—The estimates for the project as a whole, work out as follows:—

	RS.
Cost of Revenue and Public Works Department investigations	6,40,000
Compensation for Tungabhadra Reservoir	65,85,000
Abatement of land revenue capitalised for the Tungabhadra reservoir	8,23,375
Compensation for head works	60,000
WORKS—	
Tungabhadra dam, escape and head sluices	1,14,38,000
Special machinery for escape and head sluices	6,00,000
MAIN CANAL—	
Compensation	2,00,000
DISTRIBUTARIES—	
Compensation—Bellary East and West blocks	1,30,000
Abatement of land revenue capitalised	1,62,625
WORKS—	
Main canal	2,77,48,000
Main canal tunnel	36,80,000
Bellary East and West blocks	89,30,740

DISTRIBUTARIES—

Tadpatri Block—

Compensation	88,700
Abatement of land revenue capitalised	58,000
Works—Head works and canals	33,18,300

Pulivendla and Muddanur Blocks—

Compensation	1,79,200
Abatement of land revenue capitalised	94,000
Works—Head works and canals	50,08,800

Cuddapah Block—

Compensation	49,300
Abatement of land revenue capitalised	50,000
Works—Head works and canals	12,35,700

Jammalamadugu Block—

Compensation	54,300
Abatement of land revenue capitalised	40,500
Works—Head works and canals	10,71,700

Nellore Block—

Compensation for head works	7,46,000
Compensation for main canal	68,600
Compensation for distributaries	38,900
Abatement of land revenue capitalised	3,89,300

WORKS—

Dam and head works	44,90,000
Special machinery for dam and head works	4,00,000
Main canal	1,04,61,400
Distributaries	49,71,100
Establishment charges on works totalling Rs. 8,23,53,740 at 23 per cent.	1,89,41,360
Tools and plant at $1\frac{1}{2}$ per cent.	12,35,309
Leave and pension allowances at 14 per cent. on establishment.	26,51,791
Total ...	11,66,40,000

The preliminary estimates amounted to Rs. 870 lakhs. Of this 40 lakhs was allotted to compensation, which was a bad underestimate, since the compensation for the Tungabhadra Reservoir alone is now assessed at 66 lakhs, and that for Someswaram reservoir at 7 lakhs, besides the compensation for land taken up for the canals, which aggregates some 9 lakhs. The remainder of the difference is accounted for by the enlargement of the scope of the project, from a main canal of 7,000 cusecs at head to a canal of 12,000 cusecs. Bearing these two facts in mind the preliminary estimate was on the whole a good one.

It is right to say that none of the works proposed are of a very unusual nature, that they are all to be carried out on well-known ground, in a healthy climate, and in tracts where the local rates for work are established. There will be a rise in prices during execution, and on this account the local rates have in nearly all cases been increased, often largely increased, in framing the present estimates. Everything that it is possible to anticipate has been allowed for, and provision has been made for those unforeseen details that are certain to occur. On the whole it is believed that the estimates are liberal, and it may be expected with confidence that they cannot be greatly exceeded.

The estimates have been prepared according to the rules laid down and include the standard percentages for establishment and leave and pension allowances. The establishment required on large concentrated works does not reach a proportion as high as on small, or scattered, or slowly constructed works. In the present case the total charge for establishment and tools and plant, amounts to Rs. 202 lakhs, and it is impossible to suppose that it can in actual practice mount so high.

42. *Forecast of progress and expenditure.*—The pivot of the whole project is the Tungabhadra dam. It is of course an extremely costly policy to build this dam slowly, as interest accrues but no returns begin to come in till it is finished or nearly finished. In fact the loss caused by every year's unnecessary delay is practically the loss of a year's fully developed revenue, or say 40 lakhs of rupees. There will naturally be considerations of State governing the allotments, of which this report cannot take cognisance. There is however one powerful constructive reason for haste, which it is right to point out here with some emphasis. While the dam is building, floods must unavoidably be passed over it if they exceed a certain volume, a volume that is necessarily limited. Though such floods should not be a serious danger they may undoubtedly cause damage, without exaggerating which it may at least be said that those entrusted with the construction will be relieved when the permanent flood escape can be employed.

Assuming that money as required will be supplied it is quite feasible, and certainly advisable, to build the dam in less than seven years, of which one year may be devoted to preliminary preparation.

The rest of the works comprising the project should not of course lag behind the Tungabhadra dam, but it will not be necessary to complete them to their full capacity for many years. Thus for instance one tunnel only need be driven at first, not more than half the main canal need be excavated, and the same with the various blocks, and the distribution generally, though all land must be taken up and masonry works built to full size. Bearing these points in mind the following programme of expenditure has been drawn out:—

Year.	Tungabhadra dam.		Main canal.		Bellary West block.		Bellary East block.		No. 3 division.		No. 4 division.		Percentages for establishment and tools and plant.	Total for the year.	Total capital outlay.	Interest at 3¾ per cent.
	Works.	Compensation.	Works.	Compensation.	Works.	Compensation.	Works.	Compensation.	Works.	Compensation.	Works.	Compensation.				
	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.	LAKHS.
	Cost of Revenue and Public Works Department Investigations.													..	6·4	0·24
1 ..	12	8	16·1	·2	..	..	..	..	9	..	10	1·0	10·3	66·6	73·0	1·49
2 ..	18	12	32·7	·3	..	..	..	..	10	·4	10	1·0	16·1	100·5	173·5	4·62
3 ..	18	12	32·7	·3	..	..	8	·2	10	·4	26	1·2	23·2	132·0	305·5	8·98
4 ..	27	13	32·7	·3	·5	·1	8	·2	10	·4	26	1·2	25·5	144·9	450·4	14·17
5 ..	27	13	32·7	·3	·5	·1	8	·2	12	·1	26	1·2	26·0	147·4	597·8	19·65
6 ..	13	7	32·7	·3	·5	·1	8	·2	12	·1	20	1·2	21·1	116·5	714·3	24·60
7 ..	5·4	1·4	32·7	·3	·5	..	8	·2	11	·4	20	1·2	19·0	100·1	814·4	28·66
8 ..	..	..	10	..	·5	..	5	..	3	·4	10	·2	7·0	36·1	850·5	31·22
9 ..	..	..	6	..	·5	..	5	..	3	·2	8	·1	6·0	30·8	881·3	32·47
10 ..	..	..	4	..	·5	..	5	..	3	·2	7	·1	4·8	24·6	905·9	33·51
11 ..	..	..	4	..	·5	..	5	..	3	·2	5	·1	4·3	22·1	928·0	34·39
12 ..	..	..	4	..	·5	..	4	..	3	·2	5	·1	4·0	20·8	948·8	35·19
13 ..	..	..	4	..	·5	..	4	..	3	·1	5	..	4·0	20·6	969·4	35·97
14 ..	..	..	4	..	·5	..	4	..	3	..	5	..	4·0	20·5	989·9	36·74
15 ..	..	..	4	..	·5	..	4	..	3	..	4	..	3·8	19·3	1,009·2	37·48
16 ..	..	..	4	..	·5	..	4	..	3	..	4	..	3·8	19·3	1,028·5	38·21
17 ..	..	..	4	..	·3	..	2·5	..	3	..	4	..	3·4	17·2	1,045·7	38·89
18 ..	..	..	4	..	..	..	..	..	2·3	..	3	..	2·3	11·6	1,057·3	39·43
19 ..	..	..	4	..	..	..	..	..	..	..	3	..	1·7	8·7	1,066·0	39·81
20 ..	..	..	4	..	..	..	..	..	..	..	2·2	..	1·5	7·7	1,073·7	40·12
21 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,078·7	40·36
22 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,083·7	40·55
23 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,088·7	40·73
24 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,093·7	40·92
25 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,098·7	41·11
26 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,103·7	41·30
27 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,108·7	41·48
28 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,113·7	41·67
29 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,118·7	41·85
30 ..	..	..	4	..	..	..	..	..	..	..	..	..	1·0	5·0	1,123·7	42·05
Total ..	120·4	66·4	314·3	2	6·8	·3	82·5	1	106·3	3·7	203·2	8·6	201·8	1,123·7	..	..

Note.—Abatement of Land Revenue capitalized and Leave and Pension allowances are not included in the above.

43. *Revenue.*—The Revenue officer deputed for this side of the investigation has submitted a separate report giving his conclusions, which are summed up on page 15 of the resolution of the Board of Revenue No. 324, dated 29th August 1904. No one who knows the districts affected can doubt that the Revenue officer's estimates are extremely, perhaps unnecessarily, low. Nor can it be doubted that by the end of another generation the totals will be very largely increased, perhaps doubled, and that the Government will by that time be possessors of a property of immense value. Nevertheless the object at present is to anticipate what the Government, with the maximum of expenditure and the minimum of returns, may possibly stand to lose, and with this object in view the following calculation will rest upon the most prudent forecast. On the same grounds no credit will be given for various probable sources of profit, such as cultivation round the edge of waterspread of reservoirs, increased acreage under river channels, enhanced land revenue, increase under the Kurnool-Cuddapah canal, increase of second crop in the Kistna delta, the sale of waste land and tank beds, the provision of power for industrial purposes, growth of firewood and timber along the canal banks, grazing and fishing rights, etc.

Year.	First crop rice. In thousands of acres.	Rupees in lakhs.	First crop garden. In thousands of acres.	Rupees in lakhs.	Second crop rice. In thousands of acres.	Rupees in lakhs.	Second crop garden. In thousands of acres.	Rupees in lakhs.	Dry crops protected. Rupees in lakhs.	Saving in famine-relief. Rupees in lakhs.	Total of [illegible] Rupees in lakhs.	Maintenance. Rupees in lakhs.	Collection charges. Rupees in lakhs.	Total of 13 and 14.	Net revenue [illegible]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 ..	..	..	..	..	..	..	..	..	..	2·5	2·5	..	..	..	2·5
2 ..	..	..	..	..	..	..	..	..	..	2·5	2·5	..	..	..	2·5
3 ..	..	..	..	..	..	..	..	..	..	2·5	2·5	..	..	..	[illegible]
4 ..	..	..	..	..	..	..	..	..	..	2·5	2·5	..	..	..	[illegible]
5 ..	..	..	..	..	..	..	..	..	..	2·5	2·5	..	..	..	[illegible]
6 ..	..	..	..	..	..	..	..	..	..	2·5	2·5	..	..	..	[illegible]
7 ..	..	..	..	..	..	..	..	..	..	2·5	2·5	..	..	..	[illegible]
8 ..	30	1·2	11	·33	2·5	·075	5	·10	2·5	3·5	7·705	2	·210	2·21	[illegible]
9 ..	60	2·4	22	·66	5·0	·15	10	·20	2·5	3·5	9·41	2	·295	2·295	[illegible]
10 ..	90	3·6	33	·99	7·5	·225	15	·30	2·5	3·5	11·115	2	·380	2·380	[illegible]
11 ..	120	4·8	44	1·32	10·0	·30	20	·40	2·5	3·5	12·82	3	·466	3·466	[illegible]
12 ..	150	6·0	55	1·65	12·5	·375	25	·50	2·5	3·5	14·525	3	·551	3·551	[illegible]
13 ..	180	7·2	66	1·98	15·0	·45	30	·60	2·5	3·5	16·230	3	·635	3·636	[illegible]
14 ..	210	8·4	77	2·31	17·5	·525	35	·70	2·5	3·5	17·935	4	·722	4·722	[illegible]
15 ..	240	9·6	88	2·64	20·0	·60	40	·80	2·5	3·5	19·64	4	·807	4·807	[illegible]
16 ..	270	10·8	99	2·97	22·5	·675	45	·90	2·5	3·5	20·345	5	·892	5·892	[illegible]
17 ..	300	12·0	110	3·30	25·0	·75	50	1·00	2·5	3·5	23·05	5	·978	5·978	[illegible]
18 ..	325	13·0	119	3·57	27·0	·81	54	1·08	2·5	3·5	24·46	5	1·048	6·048	[illegible]
19 ..	350	14·0	128	3·84	29·0	·87	58	1·16	2·5	3·5	25·87	5	1·119	6·119	[illegible]
20 ..	375	15·0	137	4·11	31·0	·93	62	1·24	2·5	3·5	27·28	6	1·189	6·189	[illegible]
21 ..	400	16·0	146	4·38	33·0	·99	66	1·32	2·5	3·5	28·69	6	1·26	7·260	[illegible]
22 ..	425	17·0	155	4·65	35·0	1·05	70	1·40	2·5	3·5	30·10	6	1·33	7·330	[illegible]
23 ..	450	18·0	164	4·92	37·0	1·11	74	1·48	2·5	3·5	31·51	6	1·40	7·400	[illegible]
24 ..	475	19·0	173	5·19	39·0	1·17	78	1·56	2·5	3·5	32·92	6	1·471	7·471	[illegible]
25 ..	500	20·0	182	5·46	41·0	1·23	82	1·64	2·5	3·5	34·33	7	1·542	8·542	[illegible]
26 ..	525	21·0	191	5·73	43·0	1·29	86	1·72	2·5	3·5	35·74	7	1·612	8·612	[illegible]
27 ..	550	22·0	200	6·00	45·0	1·35	90	1·80	2·5	3·5	37·15	7	1·683	8·683	[illegible]
28 ..	575	23·0	209	6·27	47·0	1·41	94	1·88	2·5	3·5	38·56	7	1·753	8·753	[illegible]
29 ..	600	24·0	218	6·54	49·0	1·47	98	1·96	2·5	3·5	39·97	8	1·821	9·821	[illegible]
30 ..	600	24·0	220	6·60	50·0	1·50	100	2·00	2·5	3·5	40·10	8	1·88	9·880	[illegible]

For the preparation of an approximate forecast well within the mark it may be assumed that one half of the averages given by the Revenue officer will be reached in ten years from completion of the works, and the remainder in the ensuing thirteen years. While the works are in progress there can be no question of famine, and therefore the savings under this head may be included from the first.

This is a pessimistic view of the matter. A hopeful view would be to give a value to the various "by-products", as it were, which are mentioned above, and to assume a greater area of irrigation at the end of thirty years:—

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Year.	300,000 acres first crop (in thousands of acres).	At Rs. 4 (in lakhs of rupees).	Horse-power. 7,000 horse-power at Rs. 30 profit (in lakhs).	100,000 acres second crop (in thousands of acres).	At Rs. 3 in lakhs.	Firewood and timber.	Fishing and grazing.	4 per cent. on sale of waste lands and tank beds 150,000 acres.	Total.	Maintenance.	Collection.	Total of columns 11 and 12.	Net.	Returns as previously calculated.	Total.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 ..	..	..	..	..	..	..	..	·1	·1	..	..	..	·1	2·5	2·6
2 ..	..	..	..	..	..	..	..	·1	·1	..	..	..	·1	2·5	2·6
3 ..	..	..	..	..	..	..	..	·1	·1	..	..	..	·1	2·5	2·6
4 ..	..	..	..	..	..	..	..	·1	·1	..	..	..	·1	2·5	2·6
5 ..	..	..	..	..	..	..	..	·1	·1	..	..	..	·1	2·5	2·6
6 ..	..	..	..	..	..	..	..	·1	·1	..	..	..	·1	2·5	2·6
7 ..	..	..	..	..	..	..	..	·1	·1	..	..	..	·1	2·5	2·6
8 ..	15	0·6	2·1	5	0·15	..	0·05	·1	3·0	0·15	0·0375	0·19	2·81	5·49	8·3
9 ..	30	1·2	2·1	10	0·30	..	0·05	·1	3·75	0·30	0·075	0·37	3·38	7·11	10·49
10 ..	45	1·8	2·1	15	0·45	..	0·05	·1	4·5	0·45	0·1125	0·56	3·94	8·73	12·67
11 ..	60	2·4	2·1	20	0·60	..	0·05	·1	5·25	0·60	0·15	0·75	4·50	9·35	13·85
12 ..	75	3·0	2·1	25	0·75	0·1	0·05	·1	6·1	0·75	0·1875	0·94	5·16	10·97	16·13
13 ..	90	3·6	2·1	30	0·90	0·15	0·05	·1	6·9	0·90	0·225	1·12	5·78	12·59	18·37
14 ..	105	4·2	2·1	35	1·05	0·2	0·05	·1	7·7	1·05	0·262	1·31	6·39	13·21	19·60
15 ..	120	4·8	2·1	40	1·20	0·25	0·05	·1	8·5	1·20	0·300	1·50	7·00	14·83	21·83
16 ..	135	5·4	2·1	45	1·35	0·3	0·05	·1	9·3	1·35	0·337	1·69	7·61	15·45	23·06
17 ..	150	6·0	2·1	50	1·5	0·35	0·05	·1	10·10	1·50	0·375	1·87	8·23	17·07	25·30
18 ..	162	6·48	2·1	54	1·62	0·4	0·05	·1	10·75	1·62	0·405	2·02	8·73	18·41	27·14
19 ..	174	6·96	2·1	58	1·74	0·45	0·05	·1	11·40	1·74	0·435	2·17	9·23	19·75	28·98
20 ..	186	7·44	2·1	62	1·86	0·5	0·05	·1	12·05	1·86	0·465	2·32	9·73	21·09	30·72
21 ..	198	7·92	2·1	66	1·98	0·55	0·05	·1	12·70	1·98	0·495	2·47	10·23	21·43	31·66
22 ..	210	8·4	2·1	70	2·10	0·6	0·05	·1	13·35	2·10	0·525	2·62	10·73	22·77	33·50
23 ..	222	8·88	2·1	74	2·22	0·65	0·05	·1	14·00	2·22	0·555	2·77	11·23	24·11	35·34
24 ..	234	9·36	2·1	78	2·34	0·7	0·05	·1	14·65	2·34	0·585	2·92	11·73	25·45	37·18
25 ..	246	9·84	2·1	82	2·46	0·75	0·05	·1	15·30	2·46	0·615	3·07	12·23	25·79	38·02
26 ..	258	10·32	2·1	86	2·58	0·8	0·05	·1	15·95	2·58	0·645	3·22	12·73	27·13	39·86
27 ..	270	10·80	2·1	90	2·70	0·85	0·05	·1	16·60	2·70	0·675	3·37	13·23	28·47	41·70
28 ..	282	11·28	2·1	94	2·82	0·9	0·05	·1	17·25	2·82	0·705	3·52	13·73	29·81	43·54
29 ..	294	11·76	2·1	98	2·94	0·95	0·05	·1	17·90	2·94	0·735	3·67	14·23	30·15	44·38
30 ..	300	12·00	2·1	100	3·00	1·00	0·05	·1	18·25	3·00	0·75	3·75	14·50	30·27	44·77

If the above returns are carried for another thirty years and if it be assumed that the first crop acreage expands to 1,500,000 acres and the second crop to 400,000 acres, and that a 10 per cent. enhancement of land revenue takes place on land irrigated in the previous thirty years, some such table as follows might be drawn out:—

Year.	Returns as previously calculated.	Expansion acres first crop in thousands of acres.	At Rs. 4 in lakhs of rupees.	Expansion acres second crop in thousands of acres.	At Rs. 3 in lakhs of rupees.	Enhancement of land revenue at 10 per cent.	Total.	Maintenance.	Collection.	Total of 9 and 10.	Net 8 minus 11.
1	2	3	4	5	6	7	8	9	10	11	12
31 ..	44·77	14	0·56	5	0·15	3·34	48·82	0·14	0·20	0·34	48·48
32 ..	44·77	28	1·12	10	0·30	3·38	49·57	0·28	0·24	0·52	49·05
33 ..	44·77	42	1·68	15	0·45	3·42	50·32	0·42	0·28	0·70	49·62
34 ..	44·77	56	2·24	20	0·60	3·46	51·07	0·56	0·32	0·88	50·19
35 ..	44·77	70	2·80	25	0·75	3·51	51·83	0·70	0·35	1·05	50·78
36 ..	44·77	84	3·36	30	0·90	3·55	52·58	0·84	0·39	1·23	51·35
37 ..	44·77	98	3·92	35	1·05	3·59	53·33	0·98	0·43	1·41	51·92
38 ..	44·77	112	4·48	40	1·20	3·63	54·08	1·12	0·47	1·59	52·49
39 ..	44·77	126	5·04	45	1·35	3·67	54·83	1·26	0·50	1·76	53·07
40 ..	44·77	140	5·60	50	1·50	3·72	55·59	1·40	0·54	1·94	53·65
41 ..	44·77	153	6·12	55	1·65	3·76	56·30	1·53	0·58	2·11	54·19
42 ..	44·77	166	6·64	60	1·80	3·80	57·01	1·66	0·62	2·28	54·73
43 ..	44·77	179	7·16	65	1·95	3·84	57·72	1·79	0·66	2·45	55·27
44 ..	44·77	192	7·68	70	2·10	3·88	58·43	1·92	0·69	2·61	55·82
45 ..	44·77	205	8·20	75	2·25	3·91	59·13	2·05	0·72	2·77	56·36
46 ..	44·77	218	8·72	80	2·40	3·95	59·84	2·18	0·76	2·94	56·90
47 ..	44·77	231	9·24	85	2·55	3·99	60·55	2·31	0·80	3·11	57·44
48 ..	44·77	244	9·76	90	2·70	4·03	61·26	2·44	0·84	3·28	57·98
49 ..	44·77	257	10·28	95	2·80	4·07	61·97	2·57	0·87	3·44	58·53
50 ..	44·77	270	10·80	100	3·00	4·11	62·68	2·70	0·90	3·60	59·08
51 ..	44·77	283	11·32	105	3·15	4·15	63·39	2·83	0·93	3·76	59·63
52 ..	44·77	296	11·84	110	3·30	4·19	64·10	2·96	0·97	3·93	60·17
53 ..	44·77	309	12·36	115	3·45	4·23	64·81	3·09	1·00	4·09	60·72
54 ..	44·77	322	12·88	120	3·60	4·27	65·52	3·22	1·04	4·26	61·26
55 ..	44·77	335	13·40	125	3·75	4·30	66·22	3·35	1·08	4·43	61·79
56 ..	44·77	348	13·92	130	3·90	4·34	66·93	3·48	1·11	4·59	62·34
57 ..	44·77	361	14·44	135	4·05	4·38	67·64	3·61	1·15	4·76	62·88
58 ..	44·77	374	14·96	140	4·20	4·42	68·35	3·74	1·18	4·92	63·43
59 ..	44·77	387	15·48	145	4·35	4·46	69·06	3·87	1·22	5·09	63·97
60 ..	44·77	400	16·00	150	4·50	4·50	69·77	4·00	1·25	5·25	64·52

Such tables as the above have no claim to prophecy, but serve merely to illustrate points of view.

(Signed) A. T. MACKENZIE,
Supg. Engr., Tangabhadra Project.

31st October 1904.

APPENDIX.

Note on the Geology of the Tungabhadra Dam-site by R. Bruce Foote, Esq:, F.G.S., F.M.U.

Having by desire of Government re-visited the locality at which the topographical configuration of the country requires the location of the great dam by which it is proposed to pond back the river, and the Engineering plans having been fully explained to me by Mr. A. T. Mackenzie, I will now state the conclusions I have finally arrived at as briefly as compatible with clearness.

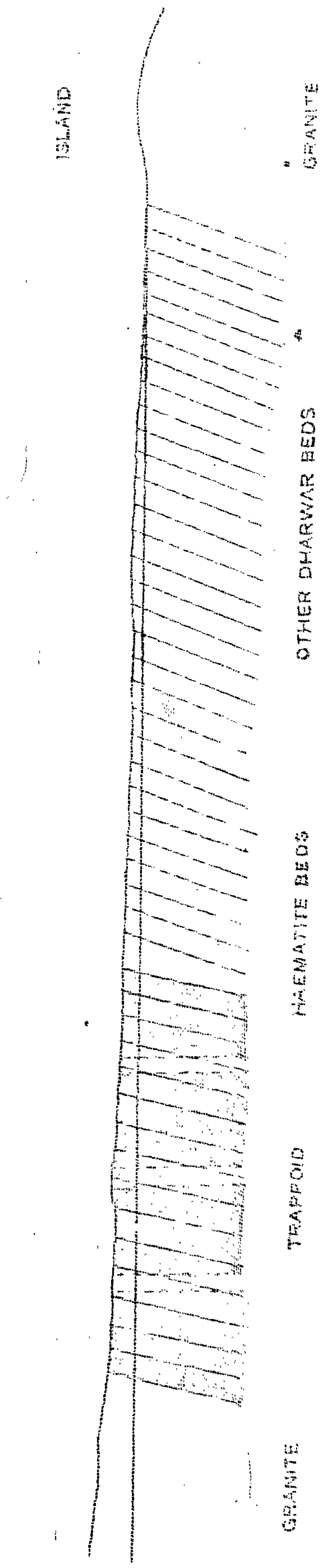
It will be seen on reference to the annexed sketch-map, which I have coloured geologically, that the rocks at the proper site for the dam consist of a band of very hard and tough "trappoids" which locally form the base of the Dharwar system and rest upon the granite which is the "country rock" of this region. From the exceeding durability and strength of the "trappoid" rock I consider it will afford a good safe foundation on which to build the proposed dam and the band which crosses the Tungabhadra north-westward from the end of the Mallapuram ridge to the western side of the Honur Malai (a small hill crowned by a ruined tower or Burj) to be abundantly wide enough to found the dam upon. From the position occupied by the beds of the trappoid which dip downward at high angles to a great depth all possibility of slipping seems completely barred. The trappoid is overlaid by a great thickness of hæmatitic beds—themselves rocks of immense strength and durability. These rocks which form the base of the western side of the great Sandur synclinal basin occupy a somewhat inverted position where they cross the Tungabhadra valley, the dip of the basin having been locally thrust over eastward by lateral pressure in ages long gone by; this makes the dip apparently a westerly one but if these beds be followed southward some distance, they will be found dipping normally eastward at an angle of 80°, whereas near Mallapuram and in the bed of the river close by, they dip westward from 75° to 90°. In rocks of such great antiquity their character for strength and stability is not at all likely to have been adversely affected by this moderate overthrust, on the contrary, the heat, developed by the great pressure which caused it, will probably have tended to render their general mass more homogeneous. The intrusion of the large pegmatite veins is likely to have had the same effect and they themselves form rock-masses of great strength and durability.

A rich source of material for the masonry of the dam, of a kind more suitable for that purpose than the Dharwar rocks near the dam site, will probably be found in the hills of grey granite a little distance north-west of what will be the end of the dam on the left bank of the river.

I give below a diagrammatic section which I think will make the matter clearer to those who have not seen the locality :—

SECTION ACROSS DHARWAR ROCKS ALONG THE MEDIAN LINE IN THE RIVER.

(DIAGRAMMATIC)



The depth to which the beds descend is unknown but is doubtless very great.

Litho., Survey Office, Madras. 1904

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Note on the Geology of the Tungabhadra Dam-site by C. S. Middlemiss, Esq., Superintendent, Geological Survey of India.

In addition to the examination and report on the Tungabhadra dam-site made by Mr. R. Bruce Foote in April 1903, a further geological examination was considered advisable owing to the subsequently excavated trench along the site having exposed a condition of the rocks which gave cause for anxiety. At the request of the Madras Government I proceeded to the place on the 15th May 1904, and under the guidance of Mr. A. T. Mackenzie, Superintending Engineer, Tungabhadra Project, was able to examine the whole length of the site as exposed by trench, river-bed and hill side, including those parts as to which there was some uncertainty of opinion.

2. Whilst the prevailing rock along the site (trappoid of Foote) is strong and durable as a whole; and especially so in the river-bed where the sounder material stands up in a jagged reef, a detailed examination shows that even there the trappoids, at their junction with the pegmatite veins, have with the latter become much cut through by planes of crushing and shearing owing to the unequal response of the two dissimilar rocks to earth stresses. In the water-worn river-bed the resulting, potentially fragmental, and comminuted state of the rocks along the junction only becomes apparent on artificially breaking the rock; but at several points in the trench to the south of the river-bed superficial weathering and percolating waters have been sufficient to bring about a nearly complete disintegration of the rocks and a conversion of them into a loose breccia set in sand and mud.

3. On this account it seems advisable that further excavations supplemented by borings should be undertaken at these spots to ascertain to what depths the rotten and shattered rock descends. In the event of that depth proving small, I do not think there will be any necessity to change the present line of the dam-site. If the contrary is the case, I would recommend a line for the site slightly to the west of the present one, where it is likely that the vein of pegmatite which runs a somewhat irregular course may be altogether avoided.

4. I am in entire agreement with Mr. Foote in considering that the trappoid rock and the pegmatite by themselves form rocks of great strength and durability. That the plane of contact between the two is, however, a source of weakness is evidenced by a laboratory examination of the pegmatites and the trappoids which shows that considerable mineralogical changes have taken place in the former with the formation of much epidote, whilst the latter for several yards from the plane of junction is shattered into small rhomboidal and irregular pieces by the crossing of several divisional planes. Apart from this local shattering, the trappoid rock which was probably once a basic lava-flow has everywhere suffered deformation as regards its minuter structure, along with considerable mineral change and reconstitution of the rock as a mineral aggregate. But this dynamic metamorphism dates back to a period anterior to the introduction of the pegmatite, and though it has left the resulting trappoid in a state that suffers by comparison with unaltered trap, yet by itself it is sufficiently strong, durable and impermeable for all practical purposes.

5. For this reason also I think the trappoid rock wherever it is found away from the junction with the pegmatite will form a very satisfactory building material for the dam (apart from its facing of dressed stones which will naturally be drawn from the grey gneissose granite of the neighbourhood).

6. Material derived from the younger trap dykes of the neighbourhood (marked green in Mr. Foote's map of the Bellary district) would probably form very suitable fine-grained and compact slabs for lining the overflow channels, etc. The nearest of these is apparently two and-a-half miles east-north-east of Hospet on the road to Hampi.

7. On the north side of the river, the site of the dam is generally free from pegmatite intrusions, and, though somewhat shattered at the surface in one or two places, will, on the whole, I think, prove satisfactory enough.

8. Further north still, the ridge running away to the place selected for the overflow channel is composed of extremely sound trappoid and need give no cause for anxiety.

Report on the Suitability of the Proposed Site of a Dam on the Penner River near Somasila, Nellore District, Madras, by R. R. Simpson, Geological Survey of India.

Position of site.—The proposed site for the dam is in latitude 14° 30′, longitude 79° ..., and about 300′ west of Someswaram pagoda, which stands on the left bank of the Penner river.

Physical details.—This river at this point is 1,200 feet in width and flows over a sandy bottom between rocky banks sloping at an angle of about 30°. In the dry season only a small flow of water passes but during the rains floods of from 30 to 35 feet are experienced.

Geological details.—The locality has been geologically mapped and described by Dr. W. King,* formerly Director of the Geological Survey of India. To the broad band of rocks upon which it is proposed to build the dam, Dr. King has given the name of the Yellaconda quartzites, the name being taken from the range of hills which the Penner river pierces before debouching on the low-lying plains of Nellore. The general rock system to which the beds belong is known as the Cuddapah system and it is considered to be possibly of pre-cambrian age.

* Memoirs, Geological Survey of India, volume VIII.

Nature of the rock.—The rock from the actual dam-site is a purplish quartzite, weathering ..., buff and brown. It is of extremely hard texture, of sub-vitreous lustre, and breaks with a conchoidal fracture and a roughened surface. Its specific gravity is 2·66. A microscopic section of the rock shows it to be composed of quartz grains cemented by a siliceous and slightly ...titic cement. A few specks of tourmaline occur. So intense has been the metamorphism to which the rock has been subjected that the boundaries of the quartz grains are practically merged into one another. Being almost pure silica the rock is insoluble in acids.

Disturbance of the rocks.—The bedding of the quartzite is massive but obscure in direction. Since the time when these sediments were deposited they have been subjected to intense pressure ~~acting apparently~~ chiefly in an approximately westerly direction. The result of this crushing ~~has been~~ to fold and fault the beds in a somewhat complicated manner; whilst at the same time white quartz has been deposited in veins, from 1 to 6 inches thick, which are found cutting across the joints and cleavage planes in a most independent fashion. The present topographical features of the country conform to these folds, the axes of which have a general N. 20 W.—S. 20 E. direction.

Cleavage.—This folding has induced upon the rocks a most pronounced cleavage, which although best displayed in the argillaceous rocks further to the west, where true slates abound, is yet plainly evident in the quartzites. At the dam-site the strike of the cleavage planes is N. 40 W. and the dip N. 50 E. at an angle of from 30° to 65°. In the fresh rock the cleavage appears somewhat coarse, but decomposition reveals cleavage planes from ⅛ of an inch to 1 inch apart.

Joints.—In addition to the fissility induced by pressure the rock is traversed by numerous sets of joints, the most pronounced of which run in a direction N. 55 E.—S. 55 W. and dip approximately vertically. Master joints are about 5 feet and simple joints not more than ... inches apart. The joint planes at a depth of 5 feet are coated with a red oxide of iron. Another system of joints are somewhat undulating but appear to have a general dip N.E. of 5°. These joints, at a depth of about 5 feet, are occasionally so open that a stick 5 feet in lengths can be pushed into its limit. They do not, however, appear to be continuous, and die out in a short distance. I am inclined to think that they are cavities produced by crushing stress.

Soft, decomposed bands in the quartzite.—On the horizon of both the cleavage planes and the flatter of the system of joint planes, bands of soft, sandy rock occur. These bands are from 1 to 6 inches thick and vary in texture from slightly decomposed quartzite to fine sand, and in colour from buff to brown and brick-red. They are apparently due both to the decomposition of the quartzite *in situ* and the filling in of joints by sandy material derived from the rock by decomposition.

Sandy debris overlying the quartzite.—On the left bank of the river on the proposed sites for the water-escape and the north-east canal, designed to irrigate the Nellore plains, the rock is covered to a depth of from 5 to 7 feet and possibly to a much greater depth further east, with quartzite debris. This deposit is composed of sand and angular to sub-angular pebbles some of which are as much as 8 inches in diameter. It is extremely porous and would oppose but the slightest resistance to the passage of water.

Depth of sand in river-bed.—In the bed of the river the thickness of the sand had not, at the time of my visit, been ascertained. Two bore-holes have been put down at a point about 500 feet below the dam-site. In the first hole coarse and fine sands were passed through to a depth of 42 feet, below which came 3 feet of rounded pebbles from ¾ of an inch to 1 inch thick. Quartzite was then encountered but the surface of it was merely broken and the hole abandoned, the reason for this abandonment being that three chisels were broken in the attempt to pierce the rock. The second bore-hole, when I visited it, was at a depth of 40 feet, where a pebble bed had been cut into. This hole is being continued.

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Conclusions.—An opinion has been asked for and will be given on the following points in connection with the building of the dam on the site proposed:—

(1) *Stability.*—The rock is undoubtedly a most suitable one upon which to found a heavy structure. It is hard, close-grained, and contains no soluble matter. No fears need, therefore, be entertained upon this score.

(2) *Percolation.*—The cleavage planes and the system of flat joints, detailed above, both dip under the dam-site from the water side, *i.e.*, north-east. The pressure of the water will, therefore, tend to compress the sandy filling of these planes, but owing to their direction of dip the sand would not be washed through. In the case of the vertical joints, striking N. 55 E. and almost in the direction of flow, these joints are not open and contain no sandy filling. I am not inclined to think that they would prove to be a source of trouble. It would be advisable to excavate the foundations to a depth of, say, 10 feet in the solid rock, to scrape out carefully all visible cracks, joints and fissure planes, and to fill in such cavities with cement or some such material as the Engineers may think suitable for the purpose. Such being done, I have every confidence that a suitably constructed dam would hold water. At the same time considerable additional security against percolation would be obtained by the laying down of an apron of a width, say, equal to the width of the dam. I understand from Mr. Mackenzie, the Superintending Engineer, that such could be done at a reasonable cost. In regard to the sandy debris through which the north-east canal is to be cut, this material will probably prove to be extremely porous. I should recommend that water-channels through it be lined.

(3) *Depth of sand in the river-bed.*—No precise information is available, but probably the first bore-hole at 45 feet was not far from the rock, if not actually upon it. Little reliance can, however, be placed upon the information from this bore-hole, as it is quite possible that the hole was in a quartzite boulder at the time of abandonment. I should recommend that the bore-holes which are, I understand, to be put down at intervals of 100 feet on the line of the dam-site, should be continued to a depth of 10 feet into the solid rocks.

(4) *Suitability of the quartzite as building material.*—Owing to its hardness and irregular fracture, the quartzite is not suitable for making dressed stone. It would, however, be perfectly satisfactory as a material for building rubble masonry.