IRRIGATION IN SOUTHERN INDIA

THE

CAUVERY, KISTNAH,

AND

GODAVERY:

BEING A REPORT ON THE WORKS CONSTRUCTED ON THESE RIVERS FOR THE IRRIGATION OF THE PROVINCES OF

TANJORE, GUNTOOR, MASULIPATAM, AND RAJAHMUNDRY,

IN THE

PRESIDENCY OF MADRAS.

PUBLISHED BY ORDER OF

THE MOST NOBLE THE GOVERNOR-GENERAL OF INDIA.

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BY THE SAME AUTHOR,

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Being a Report on the Agricultural Canals of Piedmont and Lombardy, addressed to the Honorable the Court of Directors of the East India Company.

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IRRIGATION IN SOUTHERN INDIA.

CHAPTER I.

DELTA OF THE CAUVERY.

Being anxious to complete my knowledge of the systems of irrigation throughout British India, by a personal examination of those great works already constructed, or in process of construction, in the Presidency of Madras, I sought and at once received the permission of the Honorable the Court of Directors to accomplish this object on my return from furlough. Effective measures were at the same time taken by the Honorable Court to secure the assistance of the local Government—an assistance, I may take the liberty of adding, which was subsequently granted in the most comprehensive and agreeable manner; all public records, in the form of reports, plans, or other documents illustrative of the works, being placed unreservedly at my command, and the various Officers who had been concerned in the projection or construction of the works giving me the full benefit of their personal experience and knowledge.

Landing at Madras on the 1st January, 1853, I devoted about a week to the preparatory arrangements for my journey to the works on the river Cauvery, the earliest in date, and the most complete in results of the series requiring my attention. Quitting the Presidency on the 10th, I reached Trichinoply on the 15th, and from this, as a central point, I visited the various works on which the irrigation of the Delta depends, under the pleasant and intelligent guidance of Mr. John Bird, the Collector and Magistrate of the district, to whose cordial co-operation I was indebted for most of the pleasure and profit resulting from my visit, all strictly professional aid being unfortunately denied me by the absence of the Civil Engineer of the division on duty elsewhere.

The gradual development of the system of irrigation in the Delta of the Cauvery is so full of interest and instruction, that I must attempt to exhibit its growth as clearly as the materials before me will permit. The great field wherein this progress is to be traced is the province of Tanjore—a province specially blessed by nature only in one main respect, and that is in being traversed throughout its entire breadth from west to east by the Cauvery. In other important respects it is inferior to many of its allied districts: its soil is not naturally good; it is described as consisting of a sandy alluvium generally, and in many localities the proportion of sand greatly predominates over the clay. The country has had more than the average share of internal misgovernment, and through long periods it felt the full weight of devastating wars; yet its one great gift having been always appreciated, and never long neglected, even under all disturbing influences, it has been made what it now is, literally the Lombardy of Southern India.

From the nature of the case it is probable that artificial irrigation must have been contemporary with agriculture itself in the Delta lands of Tanjore. But the first marked development of that native system, on which we have engrafted modern improvements, is traceable, I am told, to a period corresponding with the close of the second century of our own era, and to the reign of a certain Rajah Veeranum, who, judging from the number and extent of the works attributed to him, must have been a man of rare energy and enlightenment. Possibly he may get more than his fair share of credit; for when a Sovereign becomes a favorite of tradition, and the stream of history is not sufficiently clear to admit of the detection of such errors, all works of doubtful origin are generally attributed to him, and so his fame is swollen by the waifs and strays of the times that followed him. Be this as it may, there can be no question that the period of Veeranum was distinguished by great progress both in civil and religious works; for many of the gigantic pagodas, as well as the great irrigation channels in Tanjore, are supposed to date from his reign. And my attention has been drawn to the curious fact, in reference to these works, that they were all executed under an intrusive and foreign monarch, who, leading an army from the comparatively desolate tracts in the northern portion of the peninsula, established himself in the fertile southern regions. In the Teligoo country, from which the invader came, there is not a trace of any such contemporaneous works as are found in Tanjore; and it gives a striking idea of Rajah Veeranum's clearness of perception and energy of character that he should at once have appreciated the system of irrigation pursued by the subject race, and should have given to it that vast and rapid development, which, making all allowances for exaggeration, is still distinctly traceable to his reign. In the religious works of the period, several of which I had the pleasure of seeing, there are evidences of great constructive skill, immense labor, and, in some respects, marked architectural taste; while in the works of irrigation there is great boldness of design, considerable knowledge of hydraulic principles, mixed, however, occasionally with curious indications of ignorance, a massiveness of construction so disproportioned to the necessities of the case as to indicate a very exaggerated idea of the forces dealt with, and, occasionally, a neatness of finish which it was pleasant to see.

A general outline of the native system may be given in a few words. Channels of supply, proportioned in dimensions to the area of the tract dependent upon them for irrigation, were cut from the river bank, and supplied sometimes with head-sluices of masonry, but very often wanting in these necessary works. The levels of the heads were so arranged as to command a full supply in moderate floods, and the water was led to the fields by infinite numbers of smaller channels of distribution. When the level of the river surface was too low for the supply of the channels, the construction of a permanent masonry, or a temporary earthen dam, was had recourse to, and the water was thus raised to the requisite height. Of the masonry dams, several still remain; and one, bearing the name of the "Grand Annicut" (the latter being the local term for this class of works), continues to this day to play an important part in the irrigation of the Delta. Not only was the main stream thus laid under contribution, but those minor channels diverging from it as it approached the sea were also taken possession of, and hand-in-hand, so to speak, with this process of utilising the waters in moderate floods, there advanced a system of embankment whereby the waters in extreme floods were held under general control. Thus, in progress of time, there grew up over the whole surface of the Delta an extremely artificial condition of things, the cardinal points of which were, 1st, the supplying of agriculture with its first necessity, abundance of water; and, 2ndly, the protection of the property thus created on the soil from the destructive effects of an excess of water. I need scarcely add, that though the objects to be effected were discerned clearly enough, the means employed were very far from being perfect. There was one great object, indeed, not less essential to a complete plan of internal improvement, in such a district as Tanjore, than channels and embankments, which was wholly lost sight of. This was the means of intercommunication, for while the soil was fertilized and protected, its produce found its way into commerce through all sorts of difficulties, from the entire absence of roads, bridges, and other elements of free movement. Yet, with its admitted imperfections, the native administration of the waters of the Delta is worthy of high praise, and is, in point of fact, the foundation on which we have built that more perfect system, the results of which may be pointed to as one of the most memorable and gratifying proofs that here at least we have stamped our mark for good, deep on the face of the land and the condition of the people.

As subsidiary to the general plan of river irrigation, Tanks were largely employed, and were formed on such a scale as fairly to be denominated gigantic. The embankment of the Poonary Tank, in the Trichinopoly district, for example, was 30 miles in length; that of the Veeranum Tank about 10; and numerous others, of scarcely inferior dimensions, are scattered over the face of the country. These great reservoirs were variously supplied: some by channels cut direct from the Cauvery, or its main branch the Coleroon, so adjusted in level as to take advantage of the waters in moderate or high freshes, as might be most convenient; others were dependent upon minor streams across whose valleys the embankments were thrown; while others, again, were filled by the escape waters of Tanks on higher ground. All were provided with sluices for distributing the water to the fields, with escape weirs for regulating the surface level of the water, and with such other works of detail as were necessary.

The works required under the system I have thus briefly described, were constructed and maintained by the Government; the necessary funds for the formation of the works being supplied from the Treasury, while a special tax on irrigated land provided a constant annual income for the cost of repairs and establishment.

The hopeless state of confusion into which the Tanjore Government had fallen having led to the cession of the country to the English in 1801, the maintenance of the works of irrigation of course devolved upon them from that time forward; and it was not long before certain defects, inherent to the system, began to exhibit themselves in a very clear and unpleasant manner. That the causes of these, and the means adopted for their removal, may be clearly understood, I must now describe in greater detail the *topographical features of the district. Among* these, as I have already had occasion to mention, the first, and by far the most important, is the river Cauvery.

This river, rising among the Western Ghauts, drains a basin which is estimated to contain (including the Delta) between 31,000 and 32,000 square miles. Its supplying streams are fed by the rains of both Monsoons, so that from the beginning of June to the end of December its volume is abundant. From a measurement executed by Colonel Cotton, on the 4th December, 1833 (the only actual measurement I have been able to find on record), I learn that the discharge of the river at the head of the *Delta was then 16,875 cubic feet per* second, and, as the ratio of the river in high flood to its ordinary condition at this time of the year would appear *to* be nearly as 19 to 1, the volume, under the former circumstances, rises to the vast amount of 320,625 cubic feet per second. Between the two quantities thus stated the river varies during that portion of the year when its waters are essential to agriculture. From January to May its average volume may be regarded as considerably under the lower of the two estimates above given, though moderate freshes, the effects of local storms, do repeatedly occur during even these months, and more especially during March and April.

Although a small *portion of* the volume of the Cauvery is made available for irrigation before the stream enters the Delta Proper, the quantity is, relatively, so small that I need not refer in detail to it. Certain locally important channels are supplied in the Salem and Coimbatore districts, but it is not until we reach the western part of the Trichinopoly district that the capabilities of the river become fully developed. Here, at the head of what is termed the Island of Seringham,* the main river becomes subdivided into

The term Island, as applied to the tract of land called Seringham, has now become a misnomer, as it has ceased to be insular since the establishment of the Grand Annicut, by which the junction of the Cauvery and Coleroon branches, at its lower extremity, is prevented. The locality is famous as containing one of the vastest and wealthiest of the great Hindoo Pagodas, of which this part of Southern India is full. As I visited this temple in company with Mr. Bird, the collector and magistrate of the district, I saw it in its gala suit—and a very dirty suit it was—the whole aspect of the place being filthy, ruinous, and uncared for. Various portions of the huge structure, or rather series of structures, were falling to pieces from neglect of needful repairs. The great hall, the roof of which is supported, so says the legend of the place, by a thousand pillars of stone, was peculiarly dismal and dirty. The fine old columns, most of them monolithic, and all, whatever their real number may be, covered with sculpture, had been robbed of their original sharpness of outline and "dim religious" colour by successive coatings of oil-stained whitewash — a protective for which Hindoo churchwardens have fully as perverse a taste as like functionaries in more enlightened lands. Holy Bulls and Cows wandered at will in the forest of pillars, and as the former are not remarkable for amiability of temper, it was scarcely pleasant to face them. Within the enclosure walls of the Pagodas, a large town, densely populated and greatly in need of sanitary reform, has sprung up; it bears a character for immorality which rivals that of the purlieus of Westminster, its chief inhabitants being Brahmins, Hindoo widows, and dancing girls on the personal establishment of the idol. The last mentioned is, of course, the central figure of the place, though too holy for unsanctified eyes like ours to be allowed to look upon. We were permitted, however, to see and handle at will the clothes, jewels, and culinary utensils of the two channels, the southern of which retains the name of the parent stream, while the northern is called the Coleroon.

Strangely enough, I have not been able to find on record a single longitudinal section of the beds either of the main stream or of the branches. The distribution of slope is, therefore, not so precisely known as it ought to be; but I learn that the fall of the bed of the main stream, above the point of separation, is $3\frac{1}{2}$ feet per mile; that this slope is continued for a considerable distance down the Coleroon branch, gradually lessening, however, so that 70 miles below the head of Seringham it has fallen to 2 feet per mile, while onward to the sea the average slope may be estimated at one foot per mile; and that, further, the general fall of the Cauvery branch is about $4\frac{1}{2}$ or 5 inches less per mile than that of the Coleroon. In addition to its more direct and more rapid fall, the Coleroon differs from the Cauvery in having a much more direct course to the sea, and in having its volume of water but little diminished, comparatively speaking, by the drain upon it for purposes of irrigation. On contrasting the physical conditions of the two

invisible image. The latter were all of pure gold, but in forms of unredeemed ugliness and coarsest workmanship, the wide platter being the type of the flat, and the cocoa-nut cut in half that of the round dishes. The jewels, which were very numerous, showed but few beautiful samples of Indian taste in such matters. All remark, however, was silenced in a manner quite satisfactory to the proprietors, by the assurance that the united value of the display exceeded 30,000*l.*! The whole of the exteriors of the different Pagodas was covered with sculpture, occasionally good, but largely intermixed with obscenities so foul and degrading, that one wondered how it had ever entered into the imagination of man to conceive them, or having conceived, to exhibit them thus broadly in the pure sunshine.

branches, we find, accordingly, on the one hand, a larger volume, a more rapid slope, and a more direct channel than on the other. The natural result of such a combination is the progressive deterioration of that branch which is least favorably circumstanced, by the formation of deposits at its head, and the consequent diversion of the great body of the main stream into the superior channel. This tendency, in the case of the Cauvery, was recognised very soon after the province of Tanjore came into our possession; and I find it noted in the records that, in 1804, Captain Caldwell, of the Engineers, had arrived at the conclusion that if effective measures were not adopted to rectify, by artificial means, the natural differences between the two branches, the inevitable issue must be the annihilation of the Cauvery as an irrigating stream, and, as a consequence thereof, the total ruin of Tanjore. In view of a possibility such as this, remedial measures were sanctioned at that time. These, however, were apparently of a limited and by no means a radical order. The old native work called the Grand Annicut, at the lower extremity of Seringham, was raised considerably, so as to retain a larger quantity of water in the Cauvery below it, and the effect of this step was beneficial, though necessarily temporary, as the root of the evil, at the separation of the two branches, was, of course, untouched by it. For nearly 25 years, from the time at which Captain Caldwell's works were completed, an incessant struggle was maintained against the increasing tendency of the river-bed to silt up—the head and many parts of the channel were periodically cleared of deposits by manual labor—long and expensive embankments were carried across the bed of the main stream, so as to force a larger supply of water into the Cauvery branch. All these efforts, however, were ineffectual—the bed continued to rise, the supply to diminish, the extent of land under irrigation yearly decreased, the revenue was falling off, and the condition of the people was visibly becoming worse and worse. About 1829-30 the crisis had been reached; and at that time there began the series of operations of which the final issue has been the successful removal of all the evils complained of, and the establishment of the relative conditions of the Cauvery and Coleroon on an entirely satisfactory basis.

The works executed between 1830 and 1836 partook so far of the character of the measures previously adopted as to be directed against the symptoms, so to speak, rather than against the cause of the evil affecting the river-bed. They were limited to the construction of various under-sluices in the Grand Annicut and on the left bank of the Cauvery branch, through which the sand was to be swept during freshes into the Coleroon, the bed whereof, at the points selected, was considerably below that of the Cauvery. Waste weirs, to answer the same purpose as the under-sluices, were also established, and the combined effect of these various works was to clear the bed of deposits to a certain extent, though leaving it still in a condition far from satisfactory.

While these works were in progress, admirable opportunities were afforded for studying the conditions of the rivers; and from the opening of the under-sluices in the body of the Grand Annicut, one eminently satisfactory result was obtained. This work, before it was repaired by Captain Caldwell, in 1804, consisted of a solid mass of rough stones, of moderate size, 1,080 feet in length, from 40 to 60 feet in breadth, and from 15 to 18 feet in depth, stretching across the bed of the Cauvery, in a serpentine form, a favorite mode of construction in native hydraulic works, and adopted under the impression that, as all natural water-channels are tortuous, all artificial works in water* ought to be the same. The upper surface of the work was traversed by rough channels a little lower than the general levels, which were not improbably intended to act as rude substitutes for under-sluices in permitting the escape of sand over the Dam. Captain Caldwell's repairs consisted in raising the body of the Dam, levelling the surface, supplying uprights of cut stone to facilitate the formation of a temporary earthen bank to retain more water when required, and laying the stones of the upper portion in mortar. I may add, to complete this description, that some years ago a Bridge was carried across the Dam, which is, perhaps, the most singular work of the kind constructed in the nineteenth century; since, to secure foundations, it was necessary to place the piers of the arches on the Dam, and hence to follow all its sinuosities, so that the bridge has a most eccentric appearance.

When the under-sluices were to be constructed, in 1830, it became necessary to cut through the body of the Dam to a depth of 12 feet, and it was then ascertained, for the first time, that the stones of which it was composed were laid, not in hydraulic cement of any kind, but merely in clay. The new upper portion, the

* Colonel Cotton tells me that he has had his arguments, in favor of straight lines for such works as the Annicut, demolished thus, by intelligent natives: "O foolish man! Do you consider yourself wiser than God? Are not all rivers and watercourses provided by Him with crooked channels? and have you the presumption to think straight ones better? You can never prosper in your folly!"

work of Captain Caldwell, was the only part wherein mortar had been employed, and it was, accordingly, clear that the old dam had effectually withstood the floods of 1,600 years by the mere inertia of its materials. This proved a most encouraging discovery, for it was legitimately argued that if a work of such dimensions, composed only of rough stone and clay, could control the river at all periods, it was clearly possible to construct another in which the resources of European skill could be employed to reduce the dimensions by the use of superior materials, and thus to bring the cost within such limits as would fully justify the Government in undertaking it. It was further fortunate that at this period the officers in chief charge both of the revenue and irrigation departments in Tanjore were peculiarly qualified for their respective duties. The principal Collector, Mr. J. M. Kindersley, was a man of clear and comprehensive views, of great energy and character, and unwearied zeal, who thoroughly understood the necessities of his district, and was prepared to give his cordial support to such a project as promised to supply them adequately. The Civil Engineer, Colonel Arthur Cotton, was, unquestionably, the first authority on all points connected with irrigation in the corps of Engineers, and he had had excellent opportunities of becoming familiar with the Tanjore rivers. A natural genius for Civil Engineering, large acquired knowledge, singular professional daring, a strong will, and a perseverance that no obstacles could withstand, were combined in Colonel Cotton's character, and marked him out among his associates as the man best qualified for carrying into effect the novel plans that were now being entertained.

It was in the course of the year 1834 that these plans were first submitted in detail for the consideration and decision of the Government. Colonel Cotton's first general report bears date the 29th January, the second, the 7th July, and the third, the 15th July, 1834. Mr. Kindersley expresses his entire approval of the project, which had been matured in constant communication with himself, in a letter dated the 6th August, 1834. As might have been anticipated, much preliminary discussion was held on the plans, but to this I need not advert here, as its interest has now passed away. The final sanction of the Government was granted in 1836, and between February and April of that year, the works were completed. These introductory details being given, I may now proceed to describe, in general terms, the nature and results of the plans referred to. For minute professional details, I refer to the various drawings of the different parts of the works by which this report is accompanied.

Prior to the construction of any permanent works in the beds of the Cauvery and Coleroon, the area of irrigation dependent on these streams was estimated as follows:—

1. On the Cauvery.	Acres.	2. On the Coleroon.	Acres.
In the Trichinopoly Districts	16,500	In Trichinopoly	36,300
In the Tanjore ditto	488,400	In Tanjore	69,300
		In South Arcot	59,400
Total	504,900	Total	165,000

From the combined streams, therefore, a supply of water sufficient for the complete irrigation of 669,900 acres had to be provided. Now it is held, from large experience, that the constant of irrigation (as for convenience sake I may term it) for rice, in the Madras Presidency, is very nearly 3 cubic yards of water per hour for each acre during the period of the crop. This reduced to measures, which we employ in the North-West Provinces, amounts to very nearly 0·025 cubic feet per second per acre. On this standard, the total volume required for the irrigation of 669,900 acres would be 16,747·5 cubic feet per second. I have already had occasion to mention, in a former part of this narrative, that the discharge of the main Cauvery, prior to the separation at Seringham, was found to be, at a time when the river was unaffected by flood water, 16,875 cubic feet per second. There was therefore an abundant supply for the area of irrigation dependent upon the main stream. It is on analysing the distribution of the total volume of the river between the two branches, that the nature and extent of the evil, from which the province of Tanjore had so long been suffering, becomes clearly apparent. This distribution was ascertained in December, 1833, to be as follows:—

In the Coleroon Branch .	7,500	cubic feet per second.	
In the Cauvery do. . .	9,375	„	„
Total	16,875	„	„

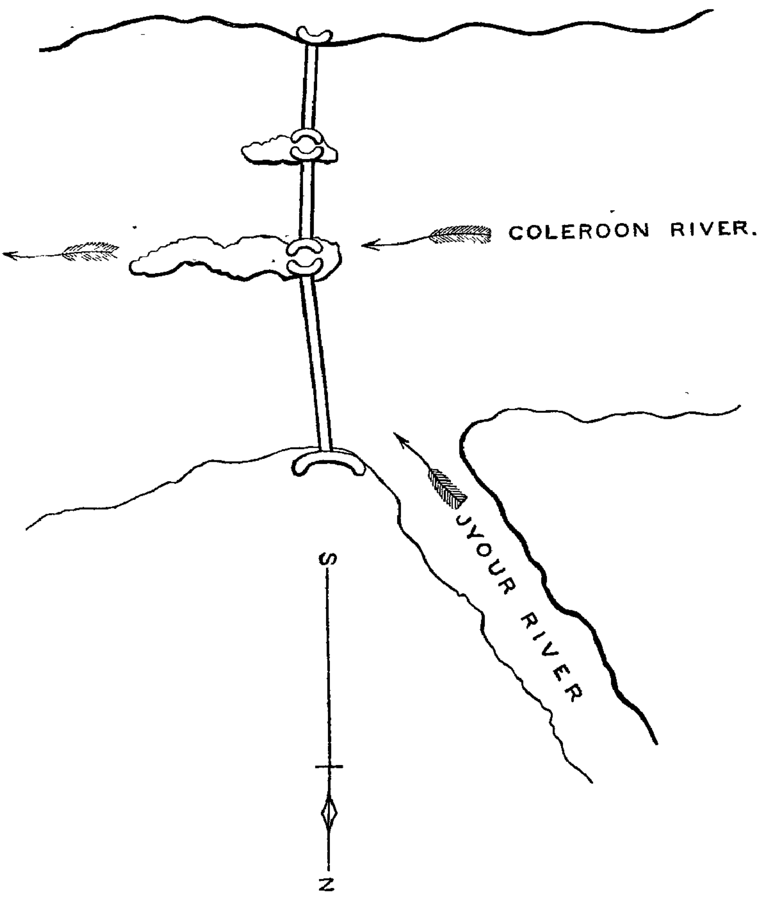
Now the quantities required for the areas of irrigation of each branch were as follows:—

Coleroon, 165,000 acres at .025 cubic ft. per second	4,125	cubic ft. per second.	
Cauvery, 504,900 „ „ „	12,622	„	„
Total	16,747	„	„

By comparing these two calculations, it becomes clear that the volume of the Coleroon was just so much too great for its area of irrigation as that of the Cauvery was too small; and that, to adjust matters, the excess in one branch must be thrown into the bed of the other. To effect this, was the great object of Colonel Cotton's plans; and the method proposed *was to throw a Dam (or Annicut) of masonry across* the bed of the Coleroon, the crown of which should be fixed at such a height as would ensure about half the supply of that branch in the average state of the river, during December and January, passing into the Cauvery. The maintenance of such a standard of division would secure, it was conceived, a fair distribution of the entire volume of the main stream between the two branches during the irrigating season.

In fixing the height to be given to the Coleroon Dam above the bed of the river, it seems to have been determined to employ simply the method of trial, assuming the elevation approximately in the first instance, and being prepared to increase or diminish it subsequently, as experience of its influence might show to be necessary. The gauge employed in estimating the quantity of water required for Tanjore, was the crown of the Grand Annicut; and it had been found by experience that when the water in the Cauvery stood *18 inches above this, the maximum supply for the* province was then entering the river. It accordingly appeared that, if provision were made for having the water level to correspond at the crowns of both works, a fair arrangement to commence with would be obtained. "I have given," says Colonel Cotton, "such a height to "the Annicut as will, so far as I am yet able to judge, "exactly correspond with the Grand Annicut; that is, "that when the water is even with the top of the one, "it will be so, also at the other." This height, in the original project, was fixed at $4\frac{1}{2}$ feet above the bed of the stream, but was subsequently modified in actual construction, as will be noted immediately.

In its original form, the Coleroon Dam consisted of a simple bar of masonry 750 yards in length, divided into three parts by the interposition of two small islands formed in the bed of the stream thus:



The northern portion was made 7 ft. 4 in., and the remainder 5 ft. 4 in. high. The body of the dam was of brick masonry, capped with cut stone, there being 1 foot in height of the latter material, and 6 ft. 4 in. or 4 ft. 4 in. of the former, according to position. The thickness throughout was 6 feet. This bar, forming the obstructive portion of the dam, rested on a foundation of masonry 3 feet deep, built on three lines of wells 6 feet in exterior diameter, and sunk to a depth of 6 feet in the sandy bed of the river. In rear of the bar, there was an apron of masonry 21 feet broad, and covered with cut stone 1 foot in thickness, carefully laid in hydraulic cement. Below the apron, a mass of rough stone, from 9 to 12 feet broad and 4 feet deep, was formed to protect the junction of the apron and river bed.

Twenty-two openings or sluices, originally 2 feet in width by 3½ in height, were distributed throughout the length of the dam, their sills being on the same level as the apron or the bed of the stream. The object of this arrangement was to afford free passage to the sand, and, if possible, to prevent the bed of the Coleroon above the Dam being raised by deposits. We shall find hereafter how ineffective it has proved.

There cannot be a question, that in adopting the dimensions just given, Colonel Cotton was treading, as it were, on the very verge of stability. In fact, a general impression prevailed that he had overstepped it; and an apparent confirmation of this impression was given, during the year following the construction of the Dam, by the occurrence of a serious accident, in the demolition of about 240 feet in length of the northern portion of the Dam. There would seem to have been no one on the spot competent to observe the cause of this accident at the time of its occurrence, and the real nature of this is a matter of speculation. The general impression, however, among the Engineer Officers consulted on the occasion, was that the fall of the water over the body of the Dam injured the apron, by displacing the cut stones and tearing up the brick masonry, so that the foundations were exposed to the force of the current, and the whole mass gave way. The breach, however, was speedily repaired, and the work remained, it may be said, almost intact until 1843, receiving minor improvements from time to time, and most satisfactorily refuting, by its continued existence in a perfectly effective form, the predictions of its entire failure, that had been recorded on the occurrence of the accident just alluded to.

During these years abundant opportunities were, of course, given for careful study of the effects of the Dam; and as some of these led, in 1843, to proposals for new and very important works, I must advert to them here.

The effects that were produced by the Coleroon Dam on the streams under its direct influence were threefold. 1st. It raised the bed of the Coleroon itself, by the slow but certain progress of deposit above the Dam. This was a contingency clearly foreseen by Colonel Cotton, and provided against by the two-and-twenty sluices through the body of the work to which I have already alluded. These, however, proved to be wholly inadequate to produce the effect expected from them; they furnished a waterway for scouring out the bed of only (22 by 2) 44 feet in width of a channel very nearly 2,200 feet broad! Their influence was practically unfelt, and in 1839 Colonel Sim recorded his opinion that "nothing less than complete cuts or openings in the Annicut from 6 to 10 or 12 feet in width will be found sufficiently influential to produce the desired effect." In 1843, such sluices were established, supplying a total width of clearance waterway equal to $129\frac{1}{2}$ feet. So far, however, as the maintenance of the Coleroon bed above the Dam at its original level is concerned, I must say that the enlarged sluices have proved of as little real use as the smaller ones; for, on examining the work in January, 1853, I found the bed above the Dam on the same general level as the crown of the work, and merely channels of about the same width as the sluices cut through the sand opposite to each set. Although, however, the primary object of their construction has not been attained, their influence, in combination with other works to be referred to presently, in maintaining an uniform distribution of the deposits, and in preventing the formation of sand-banks in front of the Dam, has doubtless been of important service. I am myself disposed to think that, so long as that form of Dam, which is in effect a continuous bar across the river bed, is preferred, the elevation of the bed above to the level of the crown must be regarded as an inevitable result, and be provided for accordingly. There is no reason to believe that, in the present case, the consequences have been of any material importance; but if, in other instances, there may be cause to fear them, the form of the Dam must be modified, as, in fact, we have done in the North West Provinces, where, instead of a continuous bar, we employ piers with moveable gates, which, being generally from twice to thrice (and, where stone is employed, six or seven times) the breadth of the piers, make, when they are lowered, the clear waterway twice or thrice the breadth of the obstructions, and hence secure a perfect scour of the river bed.

. The second effect of the Coleroon Dam was to throw a very largely increased volume of water into the Cauvery during freshes. This too was, of course, foreseen, and provided for by the following arrangements.

There being no difficulty in disposing of any quantity of water discharged into the Coleroon, that river was made the general escape channel for the Cauvery. The first outlet for the surplus volume of the latter river was established at about two miles below the separation, and consisted of an under-sluice having 20 openings or vents, giving a waterway of about 120 feet. The next escape, a little below the above, was a waste weir, having a clear waterway of 450 feet. The third was the Grand Annicut, having a clear surface waterway of about 1,050 feet, and ten sluices at low levels, giving about 60 feet more. This work has always been very effective in discharging surplus water and in clearing sand, as there is a difference of level of 9 or 10 feet between the Cauvery and Coleroon beds at its site. The fourth escape, situated about 6 miles below the Grand Annicut, was a weir of 300 feet of waterway, by which fully one-half of the flood water reaching that portion of the river is discharged. A sluice of 12 outlets, about 10 miles from the last mentioned, forms a fifth outlet. The sixth, and last of the series, is another sluice having 6 vents, and placed about 12 miles below No. 5. Eastward of this point several main channels leave the river, and pass with tolerably direct courses to the sea, supplying the means of draining off the portion of the volume of the river undisposed of by the escapes above.

These means of regulating the Cauvery might have been sufficient but for the new state of things which speedily followed the construction of the Coleroon Dam, and which, in their full extent at any rate, were not clearly foreseen. The largely increased volume of water thrown into the Cauvery branch led to great erosion of the banks and deepening of the bed. Simultaneously with these effects, the Coleroon branch was obstructed by heavy deposits and sand-banks above the Dam; the deep channel which formerly followed the left bank of the river was thrown across to the right; and, in a word, there seemed reason to apprehend an inversion of the former relations of the two branches—the Cauvery becoming the main stream, and the Coleroon ceasing to obtain its due share of water. This would have led to disastrous results in Tanjore, and measures were adopted to obtain entire command over the bed of the Cauvery. The first of these measures, executed in 1843, on the recommendation of Colonel Sim of the Engineers, was to lower the central portion of the Coleroon Dam 2 feet. This was done on a length of about 700 feet, and, of course, added considerably to the volume of the Coleroon; still, however, the enlargement of the head of the Cauvery continued, the banks were cut away, and there was great difficulty in preserving the narrow part of the island that separated the two branches. These effects were specially noted in 1844, and sanction was finally given to the construction of a masonry regulating Dam across the mouth of the Cauvery, a work suggested by Colonel Sim at the same time as he proposed to lower the crown of the Coleroon Dam.

Referring to the plans for minute details, I need only mention here that this work was executed in 1845, and that it consisted of a bar of masonry, 650 yards in length, carried across the mouth of the Cauvery. The level of the crown at the central portion was the same as that of the river bed, while 150 feet at each flank were raised from one foot to eighteen inches above it. The ordinary precautions were adopted to secure the foundations, and strong wing walls protected both flanks. The work was commenced on the 9th of February, and finished on the 20th of April, 1845, and its effects cannot be more satisfactorily described than in the words of Major Lawford, the officer in charge, under date the 5th of December, 1845. Major Lawford remarks:—

"During the whole of May, and the early part of June, "the river remained extremely low; but on the 25th of "the latter month, the freshes suddenly commenced "with great violence; and as the stream filled its "former deep bed, it attacked the defences of the banks, "which were, as usual, repaired immediately, and "strengthened. As the water subsided, it was evident "that a material change had commenced in the Cauvery, "and that the current had no longer that irresistible "force so severely felt in former seasons. A deposit of "sand was formed along both sides of the river, imme-"diately below the Dam, where, hitherto, the stream had "been extremely deep. This deposit has since gradually "extended itself lower down the river, and effectually "secures the banks in these important parts.

"In the early part of October the local rains began

" to fall, and the Cauvery was again filled, but the " stream caused no damage to the works near the river " head, except to the exposed defences at the outlets, " which suffered some injury ; and after another sub- " sidence, the river has again risen without causing " material injury to any of the defences.

" The continuance of the favorable change in the " Cauvery is now quite manifest, in the uniformity of the " section, the regularity of the current, and the absence " of masses of sand and deep holes. The stream " spreading over the entire bed, has lost its violence, " and the banks, no longer corroded and scarped, have " assumed a moderate slope; and, although the first " burst of the freshes caused a considerable outlay in the " repairs of the defences, yet not one new spot on either " bank has been attacked by the current.

" This remarkable change in the Cauvery has been " accompanied by a corresponding improvement in the " Coleroon, the bed of which is clearer and deeper than " I have ever seen it before. A strong current sets on " the centre of the Annicut; and so great has been its " effect on the bed below, that I am obliged to close the " main sluices to prevent further deepening.

" In 1842, the sands of the Coleroon, to the westward " of the Annicut, were higher than the work itself; but " where that accumulation existed, the bed is now 6 " feet lower, nor have other sand-banks been formed, but " the Coleroon, like the Cauvery, has acquired much " greater uniformity than it has had for many years.

" It is impossible to account for these changes other- " wise than as the effects of recent improvements, and " especially of the Dam at the head of the Cauvery; as "it is evident that, after each succeeding fresh, the beds "of the rivers become improved, and their regulation "more perfect. The body of water which formerly "passed in a deep concentrated stream into the Cauvery, "is now diffused over the two beds, each receiving its "just share; the thread of the stream is more direct, "and the banks are less exposed to violent currents; "circumstances which establish the correctness of "Colonel Sim's anticipations."

And farther experience has proved that the long struggle was fairly over; the means adopted have proved sufficient to control the two streams in the most satisfactory manner, for when, in 1853, I visited the works, I found the regulation of the beds, and the distribution of the water, as nearly complete as could be desired. The works themselves were in excellent condition, and the construction of a foot-bridge over the entire length of the Coleroon Dam had added greatly to its general utility.

In relation to the tract of country through which they flow, there is a marked distinction between the functions of the two branches of the main Cauvery. The Coleroon is the grand drainage channel of the Delta, and only in a minor degree an irrigating river. The Cauvery branch is essentially a channel of irrigation only, and, under average circumstances, its entire volume is devoted to agricultural purposes. Towards the sea, the main line is almost lost amongst the immense number of minor channels into which it becomes subdivided. It might naturally have been anticipated that a stream holding in suspension a considerable portion of sand or silt, and being thus drawn upon, along its course, by so many outlets, and so having its transporting power diminished, would have gradually raised its bed, and required an increased height of embankments to prevent injury to the adjoining lands. That the most careful observation during the sixteen years which have elapsed since the construction of the Coleroon Dam should have failed in detecting any proofs of such elevation, can only, I think, be attributed to the efficiency of the scour established by the various under-sluices, waste weirs, and escape channels to which I have already adverted. The river-bed has, indeed, risen to the level of the crowns of these works, but in no case beyond them; and I am assured that the irrigation has suffered no inconvenience from any alteration of level in the bed of the stream. After freshes it is observed that a slight deposit of an extremely fine rich clay takes place, which is regarded as highly fertilizing, but the quantity is so small that it does not seem to have produced any perceptible effect on the river-bed itself. All the irrigation channels, as well as the main streams in Tanjore, are solidly and substantially embanked, and the embankments are maintained so carefully that a breach is a very rare occurrence, and compensation for damaged crops has almost disappeared from the public accounts. Not but that, occasionally, a great flood does still occur, and cause mischief—this is a contingency to which every Delta must be liable; but, whereas extensive damage, and heavy remissions of revenue in consequence, were formerly the rule, they are now the exception.

The distribution of the water in the Cauvery among its main channels has, wherever necessary, been regulated on precisely the same principles as have now been described. I need not dwell on the details of these subordinate works, as they possess no special interest; but I have given plans of the Dam across the Cauvery and Vennar (one of the principal channels), as a complete illustration of the system, and one which I had an opportunity of examining personally. This fine work was constructed in 1848, with all the advantages of past experience, and its effects have been very satisfactory.

Prior to the construction of the Coleroon Dam, one great objection to it was, that by obstructing so large a portion of the section of the river, it would so contract the waterway as to raise the surface of the river very much in floods. Colonel Cotton had, indeed, shown that, assuming this effect at a maximum, it could not in great floods exceed 4½ inches; but it required some years' experience to re-assure men's minds; and it was not till it was clearly shown by actual observation that, in extreme freshes, the influence of the Dam was only to be recognised by a slight ripple on the surface of the water, that all doubt was dissipated. The increased confidence has been shown very decidedly in the construction of the bridge—a farther obstruction to the stream, but one which has produced no injurious results whatever. When the floods rise to about 8 feet above the low level, there is always a considerable back water on the Dam; and by the time they have reached their maximum height of 15 or 16 feet and filled the entire bed of the main Cauvery, the obstructive effect of the work becomes, as just remarked, barely observable.

The third and last effect of the Coleroon Dam to which it is necessary to advert, is the influence of the work on the volume of the branch across which it is thrown, and on the irrigation dependent upon this. The principle on which the division of the water in the main stream was based being, that none should flow over the Coleroon Dam until the wants of the Tanjore district had been provided for, it is clear that, in average conditions of the river, the practical effect of this arrangement would be to divert nearly the entire volume of the main stream into the Cauvery branch, and thus to leave the channel from the Coleroon dependent on the drainage, escape water, springs in the bed of the river, or other minor sources of supply. These combined had been found to furnish a volume sufficient for the irrigation on the lower Coleroon; but, as the abstraction of so large a portion of the former supply of the river, by means of the Dam, would of course very much lower its surface level, all the old channels in South Arcot would have been thrown out of use, and the levels of the village watercourses wholly deranged. A dam across the Coleroon at the head of the irrigated district of South Arcot of such height as to restore the old surface level of the water, became, therefore, absolutely necessary. It was supplementary to the upper Dam, and the sole motive for its construction was to re-establish, in the district above mentioned, the state of things destroyed by the construction of that work. It is consequently of inferior importance, and its history has by no means equal interest with that of the upper work. I may therefore only state now, that it was thrown across the river at a point 70 miles below the head at Seringham, that it consisted of a bar of masonry 8 feet high, and 8 feet broad, but having a hollow space 3 feet by 4 feet in the centre, arched over and filled with rammed sand; that it was provided with 23 under-sluices, giving 69 feet of waterway, in a total breadth of 1,901½ feet; that it had an apron of masonry in rear, 2 feet thick and 24 feet broad, and covered with 1 foot additional of cut stone, while in front and rear rough loose stones of large dimensions were employed to protect the junctions of the work with the river-bed.

The lower Dam was constructed simultaneously with the upper one in 1836, and was at first made only 6 feet in height. In 1837 two feet were added to the height, and, by the floods of that season, a formidable breach was made in the work, from the failure of the apron in rear, wherein some inferior materials had been inadvertently employed. The accident was immediately repaired, and the work has, since that period, given but little trouble, while it has effected its purpose in maintaining the irrigation of South Arcot, and a small portion of Tanjore, in a very satisfactory manner.

To complete my account of the effects of the upper Dam on the volume of the Coleroon, I may mention here that the supply of one important local division of the Trichinopoly district, was entirely cut off by it, the head of the channel of irrigation being about

8 miles *below* the Dam. This evil was easily corrected, by cutting a new head for the channel in question, starting from *above* the Dam, so that the additional height thereby secured, increased materially the efficiency of the line for purposes of irrigation.

Both Dams have inevitably interfered much with the navigation of the Coleroon (a matter of considerable importance), and the measures adopted to remove this objection to them have not been so successful as might have been desired. A lock had been provided originally in the upper Dam, but it was soon found impracticable, to work it, and it has now been converted into a double under-sluice. At this point, however, the Cauvery is open for navigation, and, by means of its main channels, preserves the communication with the sea-coast on the southern side. At the lower Dam, matters are much less satisfactory; and there are on record, so late as 1851, heavy complaints of the inefficiency of the means of navigation. I have no reason to believe that adequate measures have been adopted, since the above date, to remove the causes of these just complaints—for just they assuredly are, seeing that the works constructed by Government, and from which it has derived large pecuniary benefits, have deprived the community of facilities for transport, existing before, which in equity ought to be restored. South Arcot, the district especially affected, can ill afford to lose its water-communications, for it has no roads worthy of the name, and its produce reaches the markets or the coast with extreme difficulty. It is therefore to be hoped that the same wise liberality which has produced such admirable results on the right bank of the Coleroon, in Tanjore, may be directed towards the less fortunate district on the left bank of the same river.

I have now described, in what I hope may prove to be sufficient detail, the irrigation system of Tanjore, so far as the great works connected with it are concerned. I have tried to trace the causes to which the inefficiency of the old system was attributable, and to exhibit the different steps of the process whereby these were eradicated, and perfect control ultimately obtained over the river-beds. The permanent prosperity of Tanjore, its present large revenue, and the favorable condition of its inhabitants, so remarkable as at once to arrest the attention of even a very indifferent observer, are without question to be attributed, in large measure, to that first bold step taken by Colonel Cotton, in the construction of the upper Coleroon Dam, under circumstances of great difficulty, with restricted means, against much opposition, and with heavy personal responsibilities. It is easy for parties ignorant of such circumstances as these to find fault with the original designs, to point to the inadequacy of the original estimates, and to note the heavy additional expenses that have, from time to time, been found necessary. But the original merit of conceiving the plan of so grappling with a great river like the Cauvery, more than a mile in width, as to compel it to become an easily controlled agent, and of executing the needful works in their first form, confessedly imperfect as it was, cannot be impaired; and, as an Officer of another corps wholly unconnected with the works, I may be permitted to express my admiration of the skill and courage these display, both in their design and execution. I do this the more willingly as I am led to think that Colonel Cotton's plans are still but imperfectly appreciated in his own Presidency; and that the failure of his first estimates has been made of too much importance, and has, in fact, operated as a check to the development of like plans in other localities as well suited for them as Tanjore. To frame his estimates so that they shall represent, as nearly as all the knowledge at command permits, the liabilities of the Government in undertaking the works, is an Engineer Officer's clear and unquestionable duty. I think that great evil must ultimately result from any tampering with its principle; and as, most unfortunately, the original estimates for the Coleroon works were, as subsequently avowed, made designedly lower than they ought to have been, with a view to inducing Government to commit itself to the works, I am not surprised to find that confidence in their projector should be somewhat impaired, so far, at any rate, as probable expense is concerned. But a failure in this single respect should not surely be held to vitiate those great and tangible results about which there can be no difference of opinion, seeing that they have been felt during a long series of years in the Government Treasury and in the state of the country. It is now time that I should proceed to contrast the expenses and returns alluded to—points hitherto reserved to avoid interruptions in the description of the works themselves.

The following statement exhibits the cost of the upper Dam and its connected works from 1836 up to the present time.

	Rs.	a.	p.	£	s.	d.
Cost of original Dam constructed in 1836*	85,389	8	0	8,538	19	0
Repairing the breach and other works in 1837	25,473	5	0	2,547	6	0
Repairs and improvements in 1838.	10,475	10	0	1,047	11	0
Do do in 1839.	18,785	0	0	1,878	10	0
Repairs to the head of Seringham.	3,871	12	0	387	0	0
Cost of new head and left bank of the Coleroon for the Trichinopoly district	15,599	4	0	1,560	0	0
Extending the Dam across the small island, and lowering the middle portion of the Dam in 1843	24,938	0	0	2,494	0	0
Cost of Cauvery Dam in 1845	65,000	0	0	6,500	0	0
Various repairs between 1836 and 1849 (the latest date to which accounts are given)	1,06,249	9	0	10,625	0	0
Grand total cost of upper Dam	3,55,782	0	0	35,578	6	0

The statements from which I have compiled this result are imperfect in their details, and I cannot attempt to discriminate between the amount properly due to original works and to the ordinary annual repairs. To take the total sum expended after the construction of the Dam in 1836 as the cost of repairs would be manifestly erroneous, for the work was growing year by year to its present dimensions, by additions which were virtually new works. Yet this seems the only possible course in the present state of

For convenience sake I have converted Indian into English currency, at the rate of 2*s*. per rupee.

the accounts; and so distributed, the total amount stands thus:—

	Rs.	a.	p.	£	s.	d.
Original cost	85,389	8	0	8,539	0	0
Subsequent repairs	2,70,392	8	0	27,039	0	0
Total	3,55,782	0	0	35,578	0	0

The cost of the lower Coleroon Dam, and of the works directly connected with it, has been as follows:—

	Rs.	a.	p.	£	s.	d.
Cost of original Dam constructed in 1836	99,493	0	0	9,949	6	0
Lock and surplus sluice	8,777	0	0	877	14	0
Raising and straightening Dam in 1837	3,598	0	0	359	16	0
Repairing breach in body of Dam in 1838	25,763	0	0	2,576	6	0
Strengthening and improving the Dam in 1839	5,077	0	0	507	14	0
Constructing main northern channel of distribution.........	20,850	0	0	2,085	0	0
Constructing main southern ditto..	60,754	0	0	6,075	8	0
Various improvements to the works dependant on the Dam between 1838 and 1850, the latest date to which the accounts are available...........	2,32,366	0	0	23,236	12	0
Total cost of lower Dam and connected works	4,56,678	0	0	45,667	16	0

From these data, which, though the best I could procure, are far from being as explicit as is desirable, it is to be gathered that, up to 1849-50, the works directly connected with the Cauvery and Coleroon Dams have cost Government a total sum of Rs. 8,12,460, or

81,246*l.* I find further, on comparing two separate statements of the total expenditure on works of irrigation in Tanjore and those portions of the Trichinopoly and Southern Arcot districts which are under the influence of the waters of the Cauvery, that an additional sum amounting to very nearly Rs. 10,00,000, or 100,000*l.* has been expended. Hence the average annual expenditure for irrigation during the fifteen years adverted to, may be estimated at Rs. 1,20,000 or 12,000*l.*

Now, in estimating the returns which Government and the community have derived from this annual outlay, there are three important points to which reference must be had.

1st. The actual increase of the area of irrigation.

2nd. The increase of produce due to certain and abundant irrigation.

3rd. The permanency of the returns from the area irrigated, whatever the extent of that may be.

In illustrating these points it is not my intention to enter into any minute details. The general results will, I think, be regarded as quite sufficient; and as these have been drawn from a large mass of statistical returns, they will represent fairly the actual circumstances of the case.

First, then, as regards the increase of the area of irrigation. I find that the average quantity of land watered annually from the Cauvery and Coleroon, prior to 1836, was as follows:—

In Trichinopoly	40,061	Acres
In South Arcot...	17,365	„
In Tanjore	573,187	„
Total.........	630,613	„

The average for Trichinopoly is founded on statements extending over seven years, that for Arcot, on eleven years, and that for Tanjore on fifteen years' experience.

From 1836 onwards to 1850, the latest date to which I have detailed accounts, there is a steadily progressive increase, the fluctuations of which from year to year are exceedingly small. The returns for 1852, which were kindly shown to me by Mr. Bishop, the Collector of Tanjore, prove the progression to be continued up to that year. Trichinopoly only has remained quite stationary on the average, and even shows a slight falling off in the latter years of the series, a fact attributed to the contraction of its best market by the withdrawal of a large body of the troops at the principal station. The expenditure for grain was thereby diminished, on account of the troops alone, Rs. 2,00,000, or 20,000*l.* per annum, exclusive of the further decrease due to the departure of all that portion of the civil population which was dependant on the military. A local cause of this kind is quite sufficient to account for the diminution observed in the area of cultivation.

The average up to 1850 was as follows:—

In Trichinopoly	40,483	Acres.
In South Arcot	28,956	"
In Tanjore	647,085	"
Total after improvements...	716,524	"
Ditto before do	630,613	"
Increase since 1836	85,911	"

The increase of cultivation due to the improved system of irrigation may safely be estimated, therefore, in round numbers, at 86,000 acres, and a new domain, to this extent, has been virtually added to the districts paying the highest rate of revenue to the State, as the land has, in point of fact, been redeemed from waste.

Now, by this satisfactory result, the interests of two separate parties are affected—the Government on the one hand, and the agricultural community on the other. In dividing the benefit between them, we have to guide us the general rule prevailing in these districts, that the Government revenue may fairly be taken to represent two-fifths of the gross produce of the land: the remaining three-fifths being the share of the proprietor or tenant. In Tanjore the demand of the Government is affected by the selling price of rice, for which grain a standard price has been fixed; and when the actual market rate varies from this, rising to 5 per cent. above, or falling to 10 per cent. below it, the Government in the first instance augments, and in the second diminishes its claims in certain proportions, the precise nature of which I don't know. This sliding-scale system is, I believe, peculiar to Tanjore and the adjoining district of Tinnevelly, and is considered to work well in practice. I learn, on the best authority, that in Tanjore the land revenue averages, under all circumstances, very nearly Rs. 4¾, or nearly 9*s.* 9*d.*; in that portion of Trichinoply which is under the influence of the river irrigation, it rises to nearly Rs. 6, or 12*s.* per acre; and in the districts similarly situated in South Arcot it is higher still, being Rs. 7¼, or 14*s.* 6*d.* per acre. Excluding Trichinopoly, which has remained almost stationary, as before explained, the annual increase of Government revenue in the other two districts may be estimated as follows:—

In South Arcot......	Rs. 84,035 0 0	or	£8,403 10 0
In Tanjore	3,55,765 0 0	„	35,576 10 0
Average annual increase	4,39,800 0 0	„	43,980 0 0

I am glad to have this result, arrived at independently, confirmed by so competent an authority as Major Lawford, who, in 1845, estimates the increase at Rs. 2,50,572, or 25,057*l.* 4*s.*, and as the increase has been steadily progressive since that time, I believe my estimate to be but little, if at all, wide of the truth.

Assuming, therefore, Rs. 4,40,000, or 44,000*l.*, to be the annual increase of Government revenue (gross, not net), and making use of the proportion that bears to the gross produce of the land, we find that the agricultural community have benefited by the works, from increase of irrigated area only, to the extent of Rs. 6,60,000, or 66,000*l.* per annum. The entire expense of the maintenance of the works being borne by the State, this sum is a net addition to the resources of the people.

I have estimated the entire annual expenditure for works of irrigation, in the districts under notice, at Rs. 1,20,000, or 12,000*l.* As this rate of expenditure includes original works as well as ordinary repairs, it is manifestly unfair, as the works remain in full operation, and are a property of great value to the Government. The accounts, however, scarcely admit of these items being separated, but I will endeavour to give an approximation to the result. The Cauvery works have cost, from first to last, Rs. 8,12,460, or 81,246*l*., and supposing the average annual expenditure for repairs to be 2 per cent. on the prime cost of the works, we have an outlay on this account, between 1836 and 1850, of Rs. 2,43,720, or 24,372*l*., leaving for original works Rs. 5,68,740, or 56,874*l*. Concurrently with this outlay for the Cauvery works, a further expense for the improvement and maintenance of the vast net-work of channels, &c., spread over the districts was incurred, which has been estimated at ten lakhs of rupees, or a hundred thousand pounds sterling. Of this sum a much larger proportion comes under the head of ordinary repairs than in the case of the Cauvery works; not less, probably, than two-thirds being expended in this way. We have, therefore, the following general results:—

Total expenditure for original works between 1836 and 1850	Rs. 9,18,740	or	£ 91,874
Ditto ditto ordinary repairs ditto	8,93,720	„	89,372
Totals....................	Rs.18,12,460	„	£181,246

Now the gross returns for the same period amounted to Rs. 48,00,000, or 480,000*l*., and the net returns (obtained by deducting the amounts for ordinary repairs and 5 per cent. per annum interest on the total capital invested in the works) are Rs. 32,17,255, or 321,725*l*. 10*s*., being a clear annual return of Rs. 2,14,483, or 21,448*l*. 6*s*. on a capital of Rs. 9,18,740, or 91,874*l*., being nearly 23⅓ per cent.

Such I believe to be a fair approximation to the financial results of the irrigation works in the Delta of the Cauvery, so far as Government is concerned. If it be in error, it is in under-estimating the returns; and as the amount is considerably less than Madras officers have given, perhaps they may be dissatisfied with it. I have, however, endeavoured, without entering into needlessly minute details, to state the case as justly as the materials before me would permit; and I am certain that the Government in India, or at home, would accept the result as a justification for such further expenditure as may be required for perfecting the system, and an encouragement for extending it to other less favoured but equally promising districts.

As regards the clear gain to the community, it is so complicated by questions of cost of culture and the like, on which there is no very trustworthy information available, that I do not attempt to calculate it. The broad fact that about six and a half lakhs of rupees, or sixty-five thousand pounds sterling per annum, have been added to their gross income, from the extension of the area of irrigation, is significant enough in itself to tell its own tale.

On the second source of benefit, viz., increased produce, due to constant and abundant irrigation, a very few words will suffice. It is admitted on all hands that this increase is considerable: the highest estimate I have seen making it one-fifth, the lowest one-eighth of the gross produce, which would be from about seven to five English bushels of Paddy (unhusked rice) per acre. Supposing, however, that the increase was only one rupee per acre, we have a sum of Rs. 7,16,524, or 71,652*l.* 8*s.*, thus added to the value of the annual produce of the land.

The third advantage, viz., the substitution of a constant for a fluctuating return, is very strikingly illustrated in a paper before me, showing the gross produce in Tanjore for the last 40 years. During the earlier period the fluctuations are excessive, ranging as high as 52 per cent. During the later period, from 1836 onward, the alternations, significant of so much misery among the labouring classes, have almost entirely disappeared, and do not exceed three or four per cent. In a community dependent for its means of subsistence on the soil, the importance of having thus excluded the disturbing influence of variable seasons need not be insisted on. All the benefits of security for capital invested in cultivation are obtained; the revenue fluctuates only with the selling price of grain; and the working classes have a constant demand for their labor. The effect of these different causes in promoting the general prosperity of the country is very strikingly evidenced in the large and progressive improvement, not only of the revenue from irrigated land but of the general revenues of the province. The average of 20 years prior to the improvement of the irrigation, gives a total general revenue of nearly 43 lakhs, or four hundred and thirty thousand pounds; the average subsequent to the improvements is about 49 lakhs, or four hundred and ninety thousand pounds; thus giving to Government an annual increase of 6 lakhs, or sixty thousand pounds; being a total increase of 90 lakhs, or nine hundred thousand pounds, in 15 years.

Colonel Cotton estimates this increase much higher than I do, and his views have been adopted by the Commissioners of Public Works in their report; but if the data he adopts be examined, it will be found that they are calculated to give what seem to me to be somewhat exaggerated results.

During the same period, the value of real property has risen in the most marked manner, and it is calculated that not less than from 1½ to 2 millions sterling represent the increase to the wealth of the community under this head. The signs that indicate general prosperity are very apparent: the number of houses in the District has increased from 145,192 in 1817, to 211,588 in 1839, and is probably now not less than 300,000. The population, by the census of 1850-51, was 430 per square mile; rivalling the plains of Lombardy and Belgium; good roads, raised so as to be passable at all seasons; bridges over nearly every stream—some of them, as those across the Cauvery and Coleroon, in the Trichinopoly District, truly noble works, which even in England would excite admiration; and an immense number of minor works of communication stud the country, and ensure the means of free movement to the people at every season of the year.

I have now dwelt at sufficient, perhaps more than sufficient length, on the improvement of the Delta of the Cauvery, as attributable to the professional labors of Colonel Cotton and the Civil administration of Mr. Kindersley, Sir Henry Montgomery, and Mr. Bishop, his successors, not only in position, but in energy and skill.

I must not quit the subject, however, without remarking that, as regards distribution of the water, matters are still in the rudest possible state. No effort worthy of the term is made to regulate the supply in detail.

Wastage is excessive, as I saw many notable proofs during my journey. There is room for great improvement in all points connected with the subordinate and interior management of the water; and, as the great works are now complete, these minor questions will, doubtless, receive due attention.

It may be useful, in conclusion, to give a summary of those points of professional interest which the works in Tanjore seem to establish. These are:—

1st. That the waters of large rivers may be distributed between their branches in proportions sufficiently exact for practical purposes, by the use of Dams at the points of separation, having their crowns at such heights as experience in each case may prove to be necessary. No general rule regulating these heights seems as yet to be possible; but as the field of observation extends, it may be arrived at hereafter.

2nd. That the influence of such Dams, judiciously established on the beds of the rivers, in regulating the currents, in equalizing the distribution of deposits, and in maintaining the permanency of the sections of the beds, may be very beneficial.

3rd. That in rivers with beds of pure sand, and having slopes of 3½ feet per mile, such Dams may be constructed and maintained at a moderate expense.

4th. That the elevation of the beds of the rivers above the Dams to the full height of the crowns of these works is an inevitable consequence of their construction, and that no arrangement of under-sluices has, as yet, been effective to prevent this result.

5th. But, that where effective escapes are provided in the banks of irrigating rivers (like the Cauvery), the entire volumes of which are absorbed in irrigation, it is possible to prevent any injurious elevation of the bed by sand deposits.

6th. That in pure sand acted on by the current due to a fall in the river-bed of 3½ feet per mile, and exposed farther to the action of floods from 12 to 15 feet deep, well foundations, in front and rear, of 6 feet in depth, have been proved by an experience of 15 years to be safe.

7th. That with a vertical fall in rear of the Dam from 5 to 7 feet in height, a thickness of 2 feet of brick masonry, and 1 foot of cut stone, with a breadth of from 21 to 24 feet for the apron, have proved sufficient to insure stability, the only farther protection required being a mass of rough loose stones about 9 feet in width and 4 in depth. As a rough general rule, it would seem that the masonry apron should have a thickness equal to half, and a breadth between three and four times the vertical height of the bar forming the obstructive part of the Dam. The loose stone apron should at first have a breadth equal to 1½ times, and a depth equal to two-thirds the height of the Dam. The action at the tail of the work leading to constant additions to the loose stone soon deranges these proportions, and they are given only as guides in the first instance.

8th. That the main security of the Dam depends upon the efficient construction and careful maintenance of the apron.

9th. That in freshes the Dam speedily receives the protecting effect of a backwater on the apron; the surface level of the down-stream side being level with the crown of the work when the floods rise to 8 feet above ordinary low water, while beyond that depth the fall over the Dam gradually diminishes till in 16 feet floods it has wholly disappeared, and scarcely even a ripple on the surface indicates the existence of the mass of masonry below:

10th. That looking to the cost of the works executed between 1836 and 1853, and the increased area of irrigation due to them, the capital sunk amounts only to Rs. 6½, or about 13*s*. per acre.

11th. That after deducting every expense which the irrigation works of the Cauvery have entailed on Government, the net returns may fairly be estimated at not less that 23⅓ per cent. on the invested capital.

My inspection of the works in the vicinity of Trichinopoly having terminated on the 19th of January, I left the station on the evening of that day for Tanjore,* arriving there next morning. During the

The city of Tanjore has many objects of interest to the traveller. The great pagoda in the fort presents some of the best and some of the worst specimens of Hindoo sacred architecture I have ever seen. The Temple consists of a huge quadrangle, entered by a massive gateway covered with Mythological sculpture, generally degraded, but occasionally showing figures full of life and vigour in natural action. A debased extravagance, however, is so much more common, that one has to search for the redeeming portions. The centre of the square is occupied by a lofty pagoda of the characteristic pyramidal shape, the exterior covered with sculpture which is, almost without exception, wretchedly bad. In front of this building, however, there is a noble bull "couchant," and of gigantic size, sculptured in what seemed to me to be a compact black trap rock. It was an admirable specimen of animal sculpture, and must have required immense labor, not only in the execution, but in the transport, as no rock of the kind is found "in situ" within a hundred or a hundred and fifty miles. As nearly as I could judge, the dimensions of day various details of great interest, illustrative of the progress of the district, were communicated to me by Mr. Bishop, and arrangements having been made for

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the animal were about 16 or 18 feet in length, and about half as much in height; I roughly estimated its weight at 25 tons. It is, of course, very holy, and was covered with oil, and hung round with chaplets of flowers in great profusion. The most beautiful architectural details are in the very old buildings on the right hand side of the quadrangle. In these, the design and the execution were equally admirable, and incomparably superior to any of the more modern work. Under the arcades forming the sides of the square were innumerable symbols of Mahadeo and nature worship, so numerous, indeed, that the walls seemed to be lined with "Lingums." In the decoration of the great central pagoda, colors had been largely employed, and with very good effect. As our visit was made in the evening, it so happened that just as we entered the great square, the setting sun shone full upon the central building, and its gaudily painted walls glowed under the warm light in a very brilliant and gorgeous fashion.

The town itself is poor and dirty, but Mr. Bishop, the Resident, has succeeded in having it pierced by broad roads, which at least secure free ventilation. The Rajah's palace has the usual aspect of tawdry magnificence. It always seems as though Indian princes had insuperable objections to repairing their houses, as it is the rarest thing on earth to find one of these places which does not appear to be on the eve of tumbling down. There is one ornament to this palace, however, which, in its chaste beauty and simplicity, looks strangely out of place. It is a marble statue, by Flaxman, of the present Rajah's father, the friend of the missionary Swartz, and the protector of that devoted man during the whole period of his benevolent labors in Southern India. Even this, however, they have done their best to spoil, by substituting a plaster turban for the original marble one, on the plea, as local scandal has it, that the latter was too heavy and uncomfortable for an old man's head! The true explanation probably is, that the marble head-dress had been injured in some way, and that plaster was the only local substitute for it that could be found.

obtaining from his office all the statistical information I required, I proceeded on the evening of the 20th towards Madras,* reaching that place on the 25th.

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* I was sorry to notice, during my stay at Madras, the state of utter desolation into which the fine old tombs of the Dutch Governors of the place had been allowed to fall. A very trifling expense would suffice to maintain these in good order, as they are of massive stone work. The present aspect of the graves is revolting, and I cannot help making a note of the matter, in the hope it may attract attention.

CHAPTER II.

DELTA OF THE KISTNAH.

After resting two days at Madras, I left on the 27th for Bezwarah, on the Kistnah River, close to the head of the Delta, at which place a very interesting series of works is in progress for utilising the river supply in the irrigation of the adjoining lands in the Guntoor and Masulipatam districts.

The Kistnah, rising a little to the north of Sattara in the Bombay Presidency, and nearly on the line of 18 deg. north latitude, flows for about half its course in a direction from north-west to south-east; then turning abruptly to nearly due east it pursues its course for about 180 miles on this bearing, generally, though with local changes; and finally, making a third sweep to the southward, it enters the sea about 35 miles to the south-westward of the port and station of Masulipatam. Its total length may be estimated approximately at about 600 miles,* and the area of its drainage basin at from 25,000 to 30,000 square miles. It enters the low flat country between the high land and the sea coast at a distance of about 80 miles from its mouth, and both its banks below Bezwarah spread out in rich alluvial plains forming part of the Madras districts of Guntoor and Masulipatam.

In its progress towards the sea the Kistnah bed falls at a rate of from about 13 to 11 inches per mile; the supply of water is perennial, increasing, of course, enormously during the rainy season. As it is only after the stream has debouched into the plains that it becomes of moment as a source of supply for irrigation, my descriptive details apply only to that portion of its course which is between 70 and 80 miles in length. Throughout this distance the section of the bed varies from about $1\frac{3}{4}$ to $2\frac{3}{4}$ miles in breadth, with a depth from crest of banks ranging between 20 and 40 feet. The actual depth of water varies exceedingly, and is subject to incessant fluctuations. During the dry season, or from November to June, the supply is very small, and is chiefly derived from springs in the bed. From July to October, on the other hand, the volume ebbs and flows between great extremes, rising sometimes to the very edge of the banks, then falling 8 or 10 feet within twenty-four hours, and maintaining this height for longer or shorter periods during different seasons. While the monsoons are in full force, there is a stream of water, fully 20 feet in depth, flowing constantly, and almost uselessly, to the ocean.

It is at Bezwarah that the last and lowest outlying spurs of the hilly region to the north are found, and the site selected for the Annicut or Dam is flanked by two of these low hills.

There are certain peculiarities in the physical structure of the coast region adjoining the Kistnah which, as connected with its irrigation, deserve a little special attention. About 70 miles to the north-eastward the Godavery, another of the great rivers of the peninsula, joins the sea. The characteristics of this stream will best be given when the irrigation works upon it come under discussion, but in the meanwhile it is sufficient to say that, in co-operation with the Kistnah, it has been one of the chief agents at work during geological periods, in producing the alluvial plains to which reference has just been made. The interesting speciality to note is, that in the tract of country between the mouths of the Kistnah and the Godavery, we have an illustration of the growth of Delta lands marked by characteristic features. About half-way between the two rivers there lies a low swampy tract, which, under the name of the Colair Lake, occupies the boundary region between the two Deltas, and represents the work which it still remains for the two rivers to do before the alluvial plain can be regarded as perfect. The level of the bed of the lake is still below high tide mark, and the sea water flows into it through some of the open channels linking it with the coast. Towards the Godavery on the west, and the Kistnah on the east, the land rises with a considerable acclivity; and there seems no reason to doubt that by slow, well nigh insensible natural process, the hollow is being gradually filled in: it is now full of detached islands, which will gather new deposits around them and spread out the edges till the whole join and the swamp disappears before the growing dry land. The forces of nature work, however, very slowly, and the scale of time is too large for our necessities. The lake is an evil, to be abated, and controlled, and turned to good ends, to which the efforts of the officers on the spot are now directed, and with promise of considerable success; though it must be clear that, with such a cavity, drainage operations are not without serious difficulties, and the process of warping up by increased silt deposits has not, that I am aware of, been yet made trial of.

The Kistnah, therefore, like the majority, if not the whole, of the Deltaic Rivers, runs on the crest of an elevated ridge formed by its own deposits during a long series of years; this ridge slopes rapidly from the channel, less and less rapidly as we recede from this on either side, and to the eastward the long slope terminates in the basin of the Colair Lake. The facilities offered by this natural arrangement for the introduction of a system of artificial irrigation, are self-evident. By establishing channel heads on the river banks at the apex of the Delta, and by securing there such a height of water as the levels of the lands to be irrigated may require, we have it in our power to place the whole tract under command, and to secure the products of its culture to an extent only limited by the volume of water at our command.

It would seem strange, but that the history of our progress in India is full to repletion of such facts, that while nature had done so much, and while there was nothing whatever to conceal the practical value of her arrangements from our knowledge, seeing that they were pointed out by the native works in existence when the country fell into our hands in 1766, and still more palpably by the official reports of engineer and civil officers a few years nearer the close of the century, nothing whatever was done by the British Government to turn these advantages either to its own good, or the good of its subjects. There were, doubtless, fiscal difficulties in the way—a wretchedly inefficient revenue system left the progress of the country dependent on a class of landholders who were extravagant, debased, and utterly indifferent to the fortunes of their people, with no capital in money or mind to apply to the improvement of their estates. But a Zumindaree tenure in the hands of a proprietory always on the verge of bankruptcy (and now, happily, almost entirely bankrupt), was even then no insuperable obstacle to the progress of works like those of the Kistnah, had the true value of such works been discerned. The period between 1766 and a very recent date presents us, however, with a retrospect of about eighty years of dreary waste, varied only by the occurrence of famines or pestilences, but unrelieved by a single great work calculated to prevent a recurrence of these disasters.

While the number of these periodical calamities has been considerable, the latest in date was the most destructive of all. The total failure of the rains of 1833 affected the whole region below the Ghauts in degrees proportioned to the efficiency of the artificial resources of the different districts to supply the want of water caused thereby. It was only in the richly irrigated districts of the south, in Tanjore, Trichinopoly, and limited portions of the districts immediately adjoining these, that famine, more or less severe, was unknown. In Guntoor, where no effective irrigation existed, the results are represented in un-exaggerated terms when they are described as having been terrible. This district lies on the south or right bank of the Kistnah; it has a superficial area of about 4,700 square miles—half its soil is indifferent or unculturable, but the other half is of the richest alluvium, requiring only water to make it capable of the most abundant production. But nature has been very niggardly in her supply of this element of prosperity. Situated geographically in a region which forms the boundary between the tracts of country affected by the north-eastern and south-western monsoons, it receives a full supply from neither, while its soil is described by competent authorities * to be of such a nature as to require rather more than the average supply of moisture. The peculiarity of its position accordingly rendered the natural supply of water scanty, even for the common uses of domestic life, while for agricultural purposes it may be said scarcely to exist at all, for even the works that had been constructed in ancient times have been allowed to fall into utter ruin by the large landholders in whose estates they are situated. No district could, therefore, have been worse provided against such a catastrophe as a total failure of the rains. The destruction of life consequent upon the failure was frightful; it is estimated from statistical returns, which, though by no means free from objections, are still approximately correct, that not fewer than 200,000 people perished either from hunger, or under the virulent fever that followed in the train of the famine. At this present moment the population of Guntoor has not recovered

Report of Madras Commissioners of Public Works. Para. 289, page 117.

from the effects of that "black year," although half the period during which some of the most slowly progressive of the kingdoms of Europe double the *number of their inhabitants* has already passed by.

But the Government revenue suffered in the most formidable manner at the same time. The year after the famine, the land rent fell at once to one-half of its previous average, and the miscellaneous revenue in a considerably larger proportion. Even now, the standard income previous to the famine has not been surpassed, if, indeed, it has been reached. The loss of revenue to *the State is fairly calculated at a gross total* of upwards of 90 lakhs of rupees, or 900,000*l.* sterling. When to this amount are added the much greater losses sustained by the community, it would appear that a sum of 2½ crores of rupees, or the same number of millions of pounds sterling, would be no exaggerated estimate of the aggregate loss of property due to this deplorable calamity.*

It is to prevent the recurrence of such sacrifices of life, and the means of life, on the part of the native community, and of revenue on that of the State, that the works on the river Kistnah are designed. They embrace both banks of the river, affecting on the right the Guntoor, and on the left the Masulipatam Districts, containing an aggregate population of 1,100,000 souls, and an area of nearly 10,000 square miles, of which

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* The Madras Commissioners of Public Works (Para. 291, page 118 of their report) enter into elaborate calculations to establish these points. There seems no reason whatever to question the accuracy of their conclusions, but I have not thought it necessary to produce details, as the general results are abundantly sufficient for my argument.

one-half, or rather more than three millions of acres, may be regarded, within reasonable limits of error, as the culturable portion.

It will be remembered, that in my description of the topographical features of the Delta of the Kistnah, I had represented its prominent physical characteristic to be, the position of the great river on an elevated central ridge or back-bone—so to speak—with the country falling off gently from this towards the right and left, and having at the same time a steady general inclination in the direction of the stream, or towards the sea-coast. The facilities for the introduction of an extensive system of irrigation, resulting from such a natural distribution of slope, were cursorily alluded to, and will at once be recognised. The highest convenient point on the river's course being taken possession of as the site for a Transverse Dam, the height to be given to this work, so as to place the whole surface of the Delta under command, is a point easily determined by a line of levels across the country to be irrigated.

Nature has indicated, by unmistakeable signs, that the true position for such a Dam is at Bezwarah, about 60 miles from the junction of the river with the sea. Here there are, as formerly mentioned, two low hills, the last outlying spurs of the high lands to the north. Between them the river flows in a channel reduced to a manageable breadth of 1,300 yards, but with a depth of water so variable that no single statement would give a correct view of it—rising as it does, during the monsoons, to between 30 and 40 feet, and sinking during the dry season to, perhaps, 5 or 6. I do not find any rigidly precise information on record regarding this point; but, for convenience sake, I will assume that in average seasons the rise of the floods above the ordinary low water-mark may be taken at 24 feet; what it is exactly I don't know, but a slight difference is of no material importance. The hills in the neighbourhood of Bezwarah furnish an unlimited supply of stone for building or protective purposes; lime is readily procurable, as are all the other materials required for the work. The position is exactly at the apex of the Delta, and the height is sufficient for purposes of irrigation.

I find a deficiency in the information accessible to me regarding the distribution of the slope of the rivers, and of the details of levels throughout the irrigable region. But there is still enough at command to enable me to present an accurate general view of the capabilities of the Delta, and this is, perhaps, quite as much as is at all necessary in such a report as the present.

The fall of the Kistnah towards the sea is at an average rate of very nearly 12 inches per mile. The distance from Bezwarah to the coast at the central mouth of the river, and following the channel, is (from the maps supplied by the Madras Government) exactly 60 miles. The direct distance between the same points may be taken as averaging 40 miles on the Guntoor, and 50 on the Masulipatam banks. The fall of the country on both sides towards the sea, may therefore be estimated generally at about 18 inches per mile. Now at Bezwarah, the summer level of the river is given as 7 feet above the deep bed, and the highest freshes rise there 38 feet above the latter level, or 31 above summer water-line. I have already said that average freshes may be taken at 24 feet above the same line; and it is to economize the supply from the latter to the uttermost, that the heights given to the Dams and Sluices have been fixed. The fall of the country from the central ridge on which the river runs, is also very nearly 18 inches per mile, as a line of levels on the Masulipatam bank, 38 miles in length, showed a fall of 58 feet, and a similar line on the Guntoor side gave nearly the same result.

A due consideration of these data led to the following determinations of the levels for the proposed Dam and the heads of the channels leading from it. The sill or wasteboard of the Dam was fixed at 21 feet above the deep bed of the river, or 14 feet above summer level. As I have before expressed my conviction (in speaking of the Tanjore works), that the construction of such forms of Dam as are preferred on the Madras side of India is inevitably followed by an entire silting up of the bed of the stream above the work, I consider this step as virtually raising the deep bed at Bezwarah 21 feet above its present level; and in estimating the facilities thus obtained for the irrigation of the Delta, I shall assume this to be a state of things quite certain to be finally accomplished, and I may add, in my own opinion, at no very distant period, if we may judge from the like results elsewhere.

If the level of the flowing of the head-sluices on the flanks of the Dam be fixed on the same level as the sill of that work is, and the height of the country on the right and left be assumed at 40 feet above the deep level (which, with a possible variation of a foot or two, it actually is), then the initial digging at the heads of the irrigation channels must necessarily be about 19 feet. Sluices so fixed would, it is clear, pass off such portion of the water intercepted by the Dam as was suited to their capacities, and with the gradual increase of the freshes would receive larger and larger supplies, till the maximum was reached in the highest floods. From the moment the monsoons begin to influence the surface level of the river till this influence ceases entirely, the irrigation channels may be kept more or less supplied. I suppose that during the period of demand for water an average depth of fully 10 feet would (if possible) be thrown into the heads of the channels. Assuming the initial depth of digging to be as above, 19 feet, the fall of the country 18 inches, and the slope of the bed of the channel 9 inches per mile respectively, then the bed would strike out on the surface of the country at a distance of nearly 25 miles from the head. Hence, with a depth of water ranging between 10 and 6 feet, irrigation would be easily practicable at from 12 to 15 miles from the commencement of the excavation. If lower rates of fall are adopted, these distances would, of course, be proportionably diminished.

The actual details of the Kistnah irrigation were not settled definitely when I visited the works; and the preceding sketch does not pretend to do more than merely exhibit the relations of the river to its Delta in reference to irrigation, and to show that, by the works in process of construction, the means have been secured of spreading the water over all parts of it at a moderate cost, and with no physical obstacles likely to prove insuperable.

I may now proceed to give a short general sketch of the works alluded to, referring for purely technical details to the plans and descriptions accompanying them annexed hereto.

The great work on which the whole system of irrigation depends is, of course, the Annicut, or Dam, at Bezwarah. This has presented some peculiar difficulties in construction, from the fact that the river is concentrated into a single undivided channel between the Bezwarah and Seetunagram Hills. It has therefore been necessary to work constantly in water, and the design of the Dam has special reference to this necessity. It consists,—1st, of a broad basis of the heaviest stone that could be procured, simply thrown into the river and allowed as it accumulated to assume its own natural slopes. The exact length of this mass of stone is 3,750 feet; its breadth 305 feet; its height in front, 21 feet above the deep bed, and 14 feet above the summer level of the water. It is faced along its entire length by a casing of stone masonry 75 feet in breadth, of which the front curtain wall is 9 feet thick at bottom, 4 at top, and 14 feet high, resting on a double row of foundation wells which fill up the space between deep bed and summer line levels, being therefore 7 feet in depth. The sill or wasteboard is 20 feet in breadth, and 5 feet in thickness, 4 feet being of masonry and the upper foot of cut stone strongly bound throughout with iron clamps. The tail of the masonry casing is a flat semi-counter arch with a half chord 50 feet in length, and a versed line 10 feet in height, and this portion is terminated by a rear curtain wall running along the entire length of the Dam, 8 feet in depth and 3 feet in thickness, embedded in the loose stonework of the main body of the Dam. At a distance of 50 feet from the rear wall of the casing, a second line of masonry, somewhat irregular in dimensions, but averaging about 6 feet in thickness and 5 feet in depth, crosses the work from right to left, acting as a retaining bond to the rough stonework at the part most exposed to danger from the action of the current in floods. From this wall to the deep bed of the river the slope is worked out by the aid of rough stonework extended over a distance of 180 feet.

At the right and left extremities of the Dam, under-sluices are provided for the purpose of scouring out the silt in front of them, and thus keeping an open channel at the heads of the irrigation lines. No under-sluices have been made in the body of the Dam, and the filling up of the river-bed in front to the level of the crest of the work has apparently been accepted in this case as an inevitable result. I believe that no material evil is to be anticipated from it—none at least which cannot be easily guarded against; and I am quite satisfied that all attempts to prevent it by any such arrangements as have hitherto been adopted in Madras works will certainly fail. I am, therefore, glad to see the under-sluices restricted to those localities where they are really useful, and serve efficiently an important purpose. In the present instance, the sluices are two in number, and similar in all respects. They are situated at the extreme limits of the Dam, one at each flank, and consist of massive masonry structures founded on wells, in the usual native fashion; each has 15 vents of 6 feet in breadth each, fitted with planks and machinery for opening and closing; the level of the flooring is 3 feet below that of the heads of the irrigation channels, so that when the vents are open there will be a very efficient scour in front of them, and a deep clear channel maintained thereby through the light sandy deposits in front of the Dam. The total length of each sluice, including the thickness of the piers, is 132 feet, of which 90 feet form the clear waterway. The total breadth of the masonry platform is 171 feet, of which 18 form the front apron, 4 feet thick, protected on the side towards the stream by a curtain wall 6 feet deep, and 3 feet thick, founded on wells sunk 6 feet in the sand. The succeeding 53 feet form the breadth of the body of the sluice, of which 35 feet are occupied by the vents with their arches, piers, and cutwaters supporting a roadway of 21 feet in breadth for maintaining the communication with the sill of the Dam. The piers are 14 feet in height above the flooring, and the arches semi-circular with 3 feet radii. The flooring at this part is 6½ feet thick, supported throughout on rows of wells sunk 6 feet deep; the powerful action of the water in passing through the vents requiring special solidity here. The remaining 90 feet form the rear apron, which is 4 feet thick, and protected at its junction with the bed of the stream by a curtain wall 8 feet deep and 4 feet thick, resting, as usual, on 6 feet wells. Flank revetment walls 6 feet high at the exit from the sluices, and sinking to 3 feet at the extreme tail, confine the water to its masonry channel.

In the construction of these works no coffer-dams have yet been employed, nor is it anticipated that it will hereafter be necessary to employ them. The rough stone Dam is gradually raised to the surface, the sluices on both sides are built during the time the river is low, and consequently on dry land; through them it will be possible to divert the stream, or a sufficient portion of it to secure the works from interruption during the working season, and when the monsoons prevail and floods are too frequent or too great to be contended against, progress must be temporarily suspended. The admirable talent for organization, and the indefatigable energy displayed by Captain Orr, of the Madras Engineers, the Officer in chief charge of the Kistnah River works, have hitherto prevented any waste of time, and (if man can do it) will ensure the steady progress of the works to final completion.

The foregoing details will, I hope, be sufficient to give a fair general idea of the nature and extent of the works on which the provision of the supply of water for the irrigation of the Guntoor and Masulipatam districts from the Kistnah is dependent. The next step is to present a similar sketch of the arrangements for the distribution of this supply over the surface of the land. These are still, however, in embryo; when I visited the works (February, 1853) ground had just been broken for the channel on the left bank of the river, but no other works of any kind whatever, in earth or masonry, had been commenced. I must, therefore, be content to deal in generalities, as no useful purpose can be served by dwelling at length on details which in practice may never be adopted, or if adopted, only with material modifications.

Confining our attention in the first instance to the right or Guntoor bank of the river, I have already had occasion to mention that the total area available for irrigation may be approximately estimated at about $1\frac{1}{4}$ million of acres, and were it desirable to turn the whole of this into one vast rice field, it would be necessary to provide a supply of water equal to 32,000 cubic feet per second during the period of culture. The actual provision made, however, does not aim at any such result. The head-sluice of irrigation on the right of the river has fifteen openings, each 6 feet in width, with a clear height for the passage of water (as measured on the plans) of 11½ feet, exclusive of the archway. It may be assumed, however, that an average depth of 10 feet in the channel would represent the full supply of water at command, or which might be made available, during the season of irrigation, under the existing arrangements. It is, of course, not practicable for me to fix rigidly the actual volume of water that would pass down the channel; but with the dimensions specified, and a slope of about 12 inches per mile, the discharge would be equal to nearly 3,500 cubic feet per second, sufficient for the full irrigation of one-ninth of the entire irrigable area. It would, therefore, seem that Guntoor will be raised at once by the plans now in progress to the standard of our third-class canal districts in Northern India, and of the irrigated region between the Adige and the Mincio in Northern Italy. But there is no reason whatever to consider the present provision as a final one. With floods rising from 20 to 30 feet above summer level, and flowing at such heights for variable, it is true, but always considerable periods, the volume of the Kistnah is open to far greater demands than are now made upon it, and it will, ultimately, become a simple matter of calculation between the costs of works and the returns from them to determine how far the numbers and capacities of the channels can conveniently be amplified. It was wise to commence on a comparatively small scale, because such is best suited to the actual wants of the district and the number of its population. As the latter increases, new land will be brought under cultivation, and new demands will be made on the river; but, in the meanwhile, the power of changing nearly 150,000 acres of precarious dry into certain and profitable wet cultivation, is secured in this single district, promising to the Government an increase of revenue which may be fairly estimated at not less than two lakhs of rupees, or twenty thousand pounds per annum, and to the agricultural community a gain of fully three lakhs, or thirty thousand pounds during the same time.

The condition of the left, or Masulipatam bank, is very similar, in all natural respects, to that of Guntoor, and precisely the same extent of provision has been made for its present irrigation. A single main channel sluice with 90 feet of waterway admits the supply from the river, and the available volume of water may be regarded, in general terms, as equal to that appropriated to Guntoor. The financial results will not be inferior, and from works for which the total estimated outlay on the part of the State is fifteen and a half lakhs of rupees, or one hundred and fifty thousand pounds, the annual increase of revenue will not fall short of, and may probably, as in similar cases elsewhere, exceed the anticipated amount of four lakhs, or forty thousand pounds per annum; and if one lakh, or ten thousand pounds, be allowed for expenses of repairs and establishment, the general result will give between 19 and 20 per cent. in direct returns from land above.

The total length of the head-sluices of the irrigating channels on the right bank, including waterways of vents and thickness of piers, is 132 feet; the breadth of the platform on which the superstructure rests is 70 feet, of which 15 feet form the front apron of stone masonry protected by cut flags on the upper surface, and having a curtain wall on the river face 8 feet deep, and 4 feet thick, resting on wells in the usual way, and of the usual dimensions. The body of the platform on which the superstructure of the sluice rests, is 18 ft. 10 in. in breadth, with a thickness of 8 feet stone masonry, covered as before with cut flags, and resting on wells throughout: the height of the sluice piers is 11 ft. 6 in., the versed sines and radii of the arches 3 feet. A foot-way is provided across the top of the sluice, and a bridge of three arches of 40 feet* span each, and having a total rise, from the level of the flooring to the soffit of the arch at the crown, of 17 feet. I do not admire the architectural designs of any of these works—they are tasteless and heavy; and I can see no reason why we should not endeavour to make our irrigation works not merely useful, but, when the opportunity presents itself, ornamental also, in so far as is compatible with their objects. I advocate no extra expense in making works beautiful; but the same quantity of material may be disposed of, at precisely the

* These dimensions give a capacity of channel beyond what I have assumed as an average in a former paragraph; and during high floods a volume of water considerably in excess of what I have estimated the discharge for irrigation to be, would doubtless enter the channels, but, as an average supply with the existing means of distribution, my statement may, I presume, be considered as certainly an unexaggerated one.

same cost, in a pleasing and graceful design as in a heavy and ugly one.

The irrigation channels in Guntoor, as at present projected, are three in number. They are supplied from the common sluice-head on the right flank of the Dam, just described, and the water is retained in a common channel for a distance of 9 or 10 miles. I take it for granted that the plans supplied to me represent the true alignments of these channels, and in looking at them it is impossible to avoid remarking the apparently unnecessary tortuosity that has been permitted to disfigure them. The first 10 miles from the head-sluice, forming the portion of the channel common to the three lines of distribution, is more like an old native watercourse constructed in the infancy of the irrigation system, than a great canal designed and marked out by scientific men. It is just possible that the levels of the country may have compelled the adoption of such very contracted curves; but as no sections showing these are given, this must be merely a guess in explanation. It is, however, a great pity to sacrifice fall where it is so important to keep the level of the channel bed as high as possible; and as the alignments shown have this tendency, I may be excused for making this brief reference to them.

The extreme western channel has a course of about 50 miles running well into the heart of the district, and carrying irrigation to an extreme point, fully 50 miles from the river's bank. If about 1,200 cubic feet per second be regarded as the average volume of water available for this channel, the total surface that may be fully irrigated from it would be represented by a strip of land $1\frac{1}{2}$ miles in breadth, running along the entire length from the head to the tail. This breadth would, of course, be extended in proportion to the ratio of dry culture to wet—of waste or unculturable land to culturable—and of other physical circumstances which influence the distribution of irrigation throughout any district. Practically, the breadth of the irrigated belt dependent on the western channel would, probably, reach to not much less than three miles, under the supposed conditions. The alignment of this channel is somewhat tortuous, but the twists may be necessary to keep the bed on the highest available levels. A considerable amount of drainage, flowing from high land on the west towards the east, seems to be cut off by, and is, I conclude, received into the channel, as I find no trace of any specific arrangements for disposing of it. The tail of the channel is connected with a small stream, through which it is intended that the surplus water, when there is any, shall find an escape.

The point of departure for the three channels is at the head of a natural drainage line, which, following an extremely tortuous course through the Delta, ultimately joins the sea near the town of Vizampatam. About 10 miles further to the eastward, a second natural drainage line rises, and flows to the south in a course like the preceding; and being joined in its progress by some minor lines, falls into the sea also close to the town just mentioned. Looking comprehensively at the physical geography of this portion of the Delta, it may be divided into three well-defined tracts: first, the western, bounded by high land towards the west, and by No. 1 drainage line on the east; second, the central, bounded by No. 1 drainage line on the west, and No. 2 on the east; and third, the eastern, bounded by No. 2 drainage line on the west, and the river Kistnah itself on the east. This natural division defines clearly the distribution of the main channels over the surface of the country, and a separate line is appropriated to the irrigation of each of the separate tracts just specified. Of these I have already adverted to the western.

The next in order is the central channel. The supply for this and the eastern line occupies a common bed for about 2 miles, passing thus beyond the heads of No. 1 drainage nullah, and entering upon the central tract of the Delta. The channel for the irrigation of this diverges from the eastern line at the north-western extremity of the tract, and runs through it, on a nearly straight alignment, from north to south, until it joins No. 1 drainage nullah, to the left of, and about 2 miles above the town of Vizampatam. The length of the central channel is 30 miles, and to secure a belt of irrigated land along it, corresponding in dimensions to that specified for the western line, would require a volume of water equal to 720 cubic feet per second to be allowed to it.

The eastern channel flows centrically between the Kistnah and No. 2 drainage nullah, turning the heads of the latter completely, and thus avoiding any interference with it. Its total length is 45 miles, and the average volume of water available for use within the tract through which it takes its course, is 1,850 cubic feet per second, or sufficient for the full irrigation of 63,200 acres, being a belt of nearly $4\frac{1}{4}$ miles in breadth, under allowances similar to those made in the previous cases. This would provide most efficiently for the whole area, and would make the eastern tract the best watered of all on the right of the river.

These details will be sufficient, I hope, to give a fair impression of the proposed plans for the distribution of the water, so far as they yet go. For the interior distribution, the proprietors of the lands will themselves provide. I cannot help remarking, that such provision is certain to be made in a very wasteful and unsatisfactory way; that cuts made by natives are no better at Madras than they are amongst ourselves; that fall is always lost, repairs ineffectually executed, works allowed to go to ruin, and recklessness in the consumption of the water invariably exhibited. We have endeavoured to reduce these evils to a minimum by taking into our own hands the entire management of the minor distribution lines leading from the great channels of supply; by laying them out on the best available alignments and levels; by taking the charge of the execution and maintenance of the works, in the first instance, on ourselves; and by recovering such outlay as is necessary from the groups of villages benefiting by the different minor channels. Thus the main supplying, and the subordinate distribution channels are invariably maintained in the most effective condition possible, and the mere village water-courses only left to native control. What local objections may exist to the introduction of such a system in the Delta of the Kistnah, I cannot tell; but looking to the topography of the region, there can be no question that all physical features are in favor of it. Each main channel might be accompanied by its right and left chain of minor channels (called "rajbuhas" with us), under the superintendence of the Government officers; and the advantages which have led us to reject all other plans in favor of this, would have their full effect in Guntoor and Masulipatam, as they had on the Jumna and Ganges Canals.

In subjecting a tract of country having the natural features of the Kistnah Delta to extensive irrigation, attention to efficient drainage becomes a matter of primary importance. Two expedients have been had recourse to, to secure this: first, by clearing out the natural nullahs, Nos. 1 and 2, whereby the central and eastern belts are drained; and, second, by reinforcing the former by the aid of an artificial cut carried well to the westward, and leaving the nullah about 10 miles below its head. This cut when completed will fall into a creek connected with the sea, eight miles or so to the west of Vizampatam. It has, apparently, been considered sufficient for the drainage of the western belt to receive the rain-water into the bed of the irrigation channel, for no special arrangements to dispose of it appear on record. It is not to be supposed, however, that the drainage of the whole tract on the right of the river has yet been fully provided for. Additions to the existing means will doubtless be made as experience makes the necessity for them apparent; and the matter is one the importance of which is clearly recognised both by the officers engaged on the works, and by the Government.

Crossing now to the left bank of the river, I have to sketch the general distribution of the irrigation channels designed for the benefit of the Masulipatam district.

It will be recollected that here, as on the other side, the slope of the country is double: extending, in one direction, easterly, *from* the river, and towards the Colair Lake; in the other, southerly, *with* the river, and towards the ocean. Both slopes are taken full advantage of in the formation of the net of channels spread over the surface of this section of the Delta.

There are not the same facilities for distributing the irrigated region into separate belts, bounded by natural lines, as we found on the Guntoor side.

Two ancient channels, having all the characteristic marks of natural rivers, and called respectively the Boodaimair and Pollier, traverse the district in different directions, and for ages have been subservient to the irrigation of the Delta; acting very imperfectly, it is true, in consequence of the uncertainty of supply, and other causes of fiscal origin, but still having done valuable service in their day. The Boodaimair leaves the Kistnah at Bezwarah, and flows easterly towards the Colair Lake. Between it and the high land to the northward a belt of land, admirably adapted for irrigation, about 35 miles in length, and 5 or 6 in mean breadth, is included. The station of Ellore is at the farther extremity of this region, and for facility of reference, I may therefore term it the Ellore belt.

The Pollier (or Pulleiroo, as I find it sometimes written) has its head 24 miles lower down the Kistnah than that of the Boodaimair, and flowing in a south-easterly direction, enters the sea near the station of Masulipatam, after a very tortuous course of about 30 miles in length. The two old channels adverted to thus form the boundary lines of a second belt of irrigable land, roughly triangular in shape, and having a base of about 30 miles in length, and perpendicular height of nearly 60; these dimensions being, of course, given only in an approximate way, though near enough to the truth for all practical purposes. The important coast town of Masulipatam being situated within the tract above defined, I will refer to it hereafter, under the designation of the Masulipatam belt.

Between the Pollier and the Kistnah itself, a third tract is included, much intersected towards the coast by creeks and minor branches of the great river, but presenting some of the richest land in the district for irrigation. The shape of this also is rudely triangular, with a base, on the river, of about 35 miles in length, and a perpendicular height of nearly 20. From the most important place within its limits, I will term it the Diog belt.

Into these three separate belts, the Ellore, the Masulipatam, and the Diog, the left section of the Delta of the Kistnah may accordingly be divided with sufficient accuracy; and to the effective irrigation of each distinct works have been allotted, which I now proceed to describe.

The general supply for the entire district passes through the left head-sluice of the Bezwarah Dam, the dimensions of which are precisely the same as those of the corresponding work on the right bank, with the exception of the breadth, which is increased, as the main road from Madras crosses the head of the irrigation channel, which thus forms a bridge of communication; but in other respects the grouping and general dimensions of the works are identical on both sides of the river, and their value for agricultural purposes may also be assumed as being the same. Hence, then, I take it for granted, that 3,500 cubic feet of water per second may be calculated upon as available for consumption in the part of the Delta now under remark.

The Ellore Channel coincides for about 10 miles from its head with the old course of the Boodaimair, cutting off the twists, however, and thus economising the fall. It then runs on high levels, with a straight alignment directed upon the station of Ellore, at which it terminates. Its total length is 36 miles, and if 1,000 cubic feet per second be allotted to it as its share of the general supply for irrigation, the breadth of the irrigated belt will be $1\frac{3}{4}$ miles, supposing the whole to be watered; or making the same allowances as before for the proportion between wet and dry culture, waste land in village sites, beds of tanks, and other particulars, about $3\frac{1}{2}$ miles.

The portion of the supply destined for the irrigation of the Masulipatam and Diog belts occupies a common channel for nearly 12 miles, from the head at Bezwarah, coincident in general direction with the old Pollier, but avoiding tortuosities as much as possible. The coincidence with pre-existing lines common to both the Ellore and Masulipatam channels probably originates in economical considerations. I admit the force of these, and were it certain that no loss of efficiency in distributing the water for irrigation was to be anticipated from the generally defective alignments in such cases, the saving of outlay by using old excavations may be of undeniable importance. But the contempt for directness of course, and economy of slope, which characterize such ancient works, is generally so marked as to make the ultimate economy of adhering to them very questionable indeed. In these provinces we clung long to the use of natural hollows or pre-existing native cuts when they could be found. And often, indeed, of necessity; for the wisdom of incurring a somewhat greater present outlay to avoid a future and incessant expenditure, far greater in ultimate amount, was not then distinctly recognised. But we have come now to regard with suspicion the apparent advantages of economy of this kind, and to scrutinize them very closely lest we should be betrayed by the temptation, which is palpable enough even to unprofessional eyes, while its consequences require some familiarity with the subject for their detection and exposure. By these remarks, I do not mean to reflect on the course pursued in the cases under notice by the officers in charge of the works—there may be excellent reasons for what they have done; but for the benefit of young officers, who have their experience to gain, I take the opportunity of recording my opinion to be against the use of tortuous natural, or old artificial lines, even when the saving of expense thereby may be very clear, unless that saving materially exceeds the various sources of loss, not merely to Government, but to the irrigating community, having their origin in a system which practically throws the water into holes, from whence, to do its maximum of work, it must be presently got out again. By carrying compact channels along the highest levels, and in the most direct courses compatible with local necessities, economy of repairs, of water, of labor by the agriculturist in the distribution by detail over his fields, and of land occupied, is combined with extension to its utmost of the area of irrigation; and such manifest advantages should never be abandoned on considerations of economy of money, which, however specious at first sight, will, unless great caution be used, turn out in the end to be utterly hollow and unsubstantial.

To return, however, to my more immediate subject. The supply for the Masulipatam Belt branches off from the common channel to the left; and after flowing for about two miles in one bed, it becomes sub-divided between two branches. Of these, one flows off directly towards the margin of the Colair Lake, having a course about twenty miles in length; while the other pursues a course generally coincident with that of the old Pollier Channel, but avoiding its bends, and bearing, with curves of large radii in its alignment, on a point about three miles to the south-west of Masulipatam, where, after a course of 28 miles, it joins a transverse cut from the town just mentioned to the extreme eastern branch of the Kistnah, and into this its tail water is received, and finds its way to the sea.

It therefore appears that for the irrigation of the Masulipatam Belt, two channels, having a combined length of 48 miles, have been provided; and if 1,500 cubic feet per second be appropriated as their share of the general supply, the breadth of the irrigated tract will be between 3 and 3½ miles. It should not be forgotten that in giving these details of the irrigated areas on the different channels I have assumed that rice only will be cultivated on wet lands, and that consequently the maximum consumption of water will take place—one cubic foot per second being capable of bringing to maturity only 40 acres of this product. But if other products, less insatiable in their demands for water, be introduced, the areas will, of course, be proportionably extended.

The Diog Channel, the last of the series on the left of the river, diverges from the Masulipatam trunk line near the old head of the Pollier, and runs, throughout its whole length of nearly 42 miles, close to the Kistnah, shedding its water of irrigation over the slope to the west and southwards. There is but one obstacle to its course, namely, the passage of the eastern branch of the Kistnah; and as this can easily be effected by an aqueduct, there is no reason why the whole of the tract should not be placed under irrigation. Immediately after the passage of the eastern branch of the Kistnah, a line of irrigation is projected to the westward, following the higher levels in the direction of the branch, but avoiding minute twists, and shedding its water over the slope to the south. The Diog Channel therefore consists of a trunk line, 30 miles in length, and a south and west branch, 12 and 15 miles in length respectively—in all, 57 miles. From the peculiar distribution of the channels, the irrigated belts are all thrown on one side of those towards the interior of the tract, and a larger amount of rich alluvial soil than usual will have the only means of fertility it requires now supplied to it abundantly. The crests of the slopes are occupied by the reservoir lines of supply, and the minor distribution lines may be laid out with excellent effect. The ancient productiveness of the region—now only a matter of tradition—will inevitably be restored; and in the lower portion especially, where the crests both of the longitudinal and transverse slopes of the Delta are occupied by channels, it may fairly be hoped that a few years' continued exertion will place the agricultural community in a more prosperous state than they could have ever been, even during the best of by-gone times.

Of the total supply, 1,000 cubic feet per second may be appropriated to the irrigation of the Diog Belt; and this would be sufficient for a breadth of about 2½ miles along the entire course of the main channel and the lower branches. This completes the proposed provision for the present wants of the left section of the Delta of the Kistnah.

Thus, then, we find that the Kistnah Annicut or Dam is designed to supply nearly 290 miles of channel, judiciously distributed on both banks of the river; that it is perhaps below its capabilities to say that it secures, during the season of cultivation, not less than 7,000 cubic feet of water per second, which is sufficient to bring to maturity 280,000 acres of rice cultivation, and probably 350,000 of mixed rice, sugar, and possibly cotton; that a moderate estimate of the ultimate returns from this increased area of irrigation is Rupees 6 lakhs, or 60,000*l.* per annum, to the Government, and 9 lakhs or 90,000*l.* to the agricultural community; that failure of the monsoons will, hereafter, cease to be a fearful calamity; that where neither man nor beast can now exist from the want of water for the common purposes of life, there will, in all time to come, be an abundant supply for every want, domestic and agricultural; and finally, that the whole of these results, which, after all, are only a portion of the benefits to be anticipated from the works under review, will be executed without strain on the resources of the state, the total estimated outlay amounting only to 15½, though it may possibly rise to

20 lakhs of Rupees or 200,000*l*. I may, therefore, safely say, that among the irrigation works executed or in progress of execution in the presidency of Madras, there are none likely to be more effective in their action, or more truly creditable to the character of the Government in their ultimate results, than those now rapidly advancing to completion under the skilful superintendence of Captain Orr and his associates, of whose personal kindness and attention, during my short visit to Bezwarah, I entertain a grateful recollection.

As regards the drainage of the left section of the Delta, the arrangements are generally similar to those formerly described on the right bank of the river. The old channels are maintained for this purpose, and their action is reinforced by new artificial cuts, carried on approved levels and alignments. Of the latter, a main line passes from the western margin of the Colair Lake to the sea, and will carry off the surplus water from the region adjoining that great basin. As before, however, the details of drainage are as yet scarcely determined; but as the importance of the object is clearly recognised, they will be perfected in due course.

There remains but one other point to advert to in relation to the Kistnah works, and that concerns the facilities for internal navigation afforded by the existence of so many lines of canal, with full volumes of water and moderate slopes, intersecting the country in all directions, and capable of easy connection with the central river. The means of communication by roads are very imperfect at best, and during the monsoons, transit by land may be described as impracticable; but every irrigation channel may become a highway for boats and the whole produce of the Delta be conveyed by such means from the interior to the sea coast, or from one mart in the interior to another. To maintain the freedom of circulation between the river and the channels, masonry locks have been provided near both flanks of the Dam at Bezwarah. These works are substantial structures of stone masonry, with chambers 150 feet in length and 16 in width, fitted with all the requisite machinery in gates, sluices, &c., for passing craft from the level above the Dam to that below it, and *vice versâ*. They seemed to me to be open to but one objection, due to their being placed in what seemed to me too close a proximity to the head-sluices of the channels and the under-sluices of the Dam. On the right bank, the lock is only about 250 feet from the former of these works, and 800 feet from the latter; while on the left—the most important of these distances—that from the under-sluices is diminished by nearly one-half. Now there is always action, more or less violent, in the current near the Dam, and this becomes exaggerated when the sluices are in operation. Judging from observations made on similar works in similar positions elsewhere, I fear that craft entering the locks will do so with considerable inconvenience, and occasionally with serious risk. Farther, the works themselves are much exposed to accidents; and experience on the Godavery, as will be shown presently, proves that this evil is far from being an imaginary one. I admit at once the inconvenience of detaching these works from the general series—they then require separate supervision, the cost is higher, and the compactness of the design is interfered with; but allowing their full force to all such objections, they *cannot equal the inconvenience and injury consequent* on the partial or total destruction of the locks, or even their prolonged inefficiency while under frequent repair. The result inevitably is, that native confidence in the works is impaired, and men are unwilling to risk their boats or their goods under circumstances where both are exposed, if not to utter loss, certainly to detention and the injury consequent upon it. Locks directly connected with Annicuts have not hitherto been *successful* works: they have failed entirely on the Cauvery, they are constantly being damaged on the Godavery, and I have no doubt that one cause of these accidents has been the unfavorable positions in which the locks have *been placed—with reference to the action* of the current. I would therefore have been disposed, myself, to have carried the heads of the navigable channels considerably farther away from the flanks of the Annicut than they now are, and to have borne the additional expense caused by the greater length of channel thus rendered necessary, which, however, after all, would have been very immaterial, if security and efficiency beyond what now exist, *could thereby have* been *insured for* the internal navigation.

As subordinate to the great system of irrigation, of which I have now completed the sketch, I may mention that a large number of tanks are scattered over *the surface of* the Delta on both banks of the Kistnah; that these have been allowed to fall into a deplorable state of dis-repair, under the inefficient native surveillance on which they are dependent; *but that their restoration* and maintenance as reservoirs of supply are essential parts of the project for re-establishing the agricultural prosperity of Guntoor and Masulipatam. It will have been gathered from my remarks on the characteristics of the river that the Kistnah is very spasmodic; that its volume ranges from the immense to the very small; that for short periods it carries water enough to flood its whole Delta, while at others not a field can be irrigated from it. The great object of the engineer is to convert such spasmodic efforts into regular and continuous action—to gather in the harvest, as it were, and to store it in garners against the time of want. The flood-time is the harvest, and the tanks are the garners: the former is taken advantage of to the fullest extent by the irrigation channels, on properly adjusted levels, and the latter receive the surplus supplies to be carefully retained until the demand for them arises. The important action of the tanks in the general scheme will, therefore, be readily recognised, and their number will have to be proportioned to the extent of storage area required for the volume of water necessary to bring the cultivation to maturity. So long as the river feels the influence of the monsoons, and is sufficiently high to feed the irrigation channels, and thus to irrigate the country directly, the tanks are passive, and merely retain the water. When the monsoons cease, and the irrigation channels are dry, the tanks become active, and each sustains an area of cultivation proportioned to its own size. I shall have occasion, hereafter, to advert more in detail to the tank irrigation in the Madras Presidency; a system of which the origin is so remote in date as to be lost in the past, and of which the examples existing and ancient are so truly stupendous as not to be looked at without wonder. I need not, therefore, dwell longer at present upon it; but having by this short reference to it completed my description of the works on the Kistnah, I may now pass on to those of the Godavery.

CHAPTER III.

Having left Bezwarah on the 1st of February, I reached Dowlaisweram near Rajahmundry, the head-quarters of the Irrigation Department on the 3rd, and devoted the succeeding eight days to a personal examination of the various works in the vicinity, under the guidance of Major Frederick Cotton, of the Madras Engineers, the officer in chief charge of the operations within the Delta of the Godavery. This association was of special advantage to me, and I cannot express more strongly than I feel, my sense of Major Cotton's personal kindness in accompanying me to the different points I was anxious to visit, and in giving me unreserved access to all his sources of information, public and private. It is to these, and to the reports of his brother, Colonel Arthur Cotton, that whatever of interest or value which may be found in the following descriptive details is to be attributed, my own work being limited to the arrangement of materials, and the record of such personal impressions as my inspection of the works left on my mind.

There is one point of view from whence the recent periodic famines that have desolated different parts of India may be looked at with satisfaction. They have been the precursors of all those great works which of late years have honorably marked the progress of public improvements for agricultural objects. To the famine of 1837-38, Northern India owes the magnificent project of the Ganges Canal; to the like visitation of 1833-34, Southern India is indebted for the extensive works on the Kistnah already described; and to the same source, the yet more extensive operations in the Delta of the Godavery may be proximately traced. This relation of cause and effect between two such series of events is doubtless a very natural one, for the disease was eminently suggestive of its own remedy; but it was long before the connection was practically recognised, and in many influential minds the recognition has scarcely been made even at this hour. It seems a very simple process of reasoning to infer that if the failure of the natural supply of water, however obtained, be the cause of famine, the removal of this cause by furnishing an artificial supply, is the natural and legitimate cure for the great physical and financial evils to which it leads. But the question in its simple form becomes complicated by all sorts of doubts and difficulties when the effort is made to put the remedy in action, and few great undertakings have been more affected in their origin and progress by such a state of things than that whose object is to banish famine from the Delta of the Godavery, by utilizing the waters of this noble river.

The effects of the famine of 1833-34 were felt with great severity throughout the districts of Rajahmundry and Masulipatam traversed by the Godavery. The few irrigation works existing at that period were wholly inadequate, not to the prevention, for to that they never aspired, but to the slightest mitigation of the scourge. Their heads were on levels so much raised above the bed of the river, that it was only in high floods that any water entered them at all. During the season of dearth there was no monsoon, and consequently there were no freshes. The lands were therefore sterile, and the agricultural population more than decimated. The Government revenue fell immensely, and what was worse, continued falling year after year, till it seemed as though districts blessed by nature far beyond the average standard were destined to become desert wastes.

It was not until the year 1844 that any energetic movement was made for the rectification of this state of things. A yearly deficit of revenue amounting to 5 lakhs of rupees (50,000*l.*) from a single district, and a steady decrease in the numbers of the people throughout the Delta, forced on the Government a consideration of the means whereby such disastrous results might be averted. Fortunately, every step in the progress of works for irrigation in India furnishes an advanced point of departure for new designs. In Southern India the results to the Government and the community, of which some actual examples have already been given, are invariably so great that the wonder is not that larger projects should be proposed by the engineers, for that is a natural result of professional feeling and interests, but that Government itself should not search out, and seize upon with avidity, every available opportunity of investing its capital in ways so productive to its own resources, and so conducive to the good of the community. In the present instance, there were the eminently successful results of the works on the Cauvery and the Coleroon to appeal to; nearly eight years' experience had tested the efficiency and proved the stability of these works; and their results on the revenue of the state, and the prosperity of the districts under their influence, were such as only distempered minds could question, while reasonable and practical men never thought of doubting them. It was evident to all familiar with the characteristics of the Deltas of the Cauvery and the Godavery respectively, that in the natural elements of productiveness, the advantage was with the latter. It has a nobler and more constant river flowing through it; a topography better adapted to irrigation; a richer soil and a superior geographical position, admitting of the cultivation of products more varied and more valuable than the simple rice staple of Tanjore. Hence, then, on the submission of the projects for the works in 1844, they were faverably received by the local Government, submitted to, and in due course, about two years later, were sanctioned by the home authorities.

As preliminary to a description of the works, I must endeavour to give as clear a sketch as I can of the supplying river and the general features of the country, in so far as these are directly connected with its capacity for irrigation.

With its heads situated about the parallel of 20 degrees north latitude, and between 72 and 73 degrees east longitude, and consisting of a perfect network of channels, the Godavery has a course in rude parallelism to that of the Kistnah, which may be roughly estimated at about 650 miles in length. Its basin of drainage has, however, fully twice the capacity of that of the Kistnah, and its stream is swollen by a series of great feeders on both sides, collecting the waters of a tract of country not less than 60,000 square miles in extent, and consisting of mixed mountain and plain surfaces. Its whole valley is under the full influence of both monsoons, and its supply is perennial; being comparatively small, of course, during the dry season, but enormously increased during the rains. It is calculated that, at the minimum height of the stream during the year, a volume equal to somewhat more than 3,000 cubic feet per second may always be reckoned upon, while during the rains the available supply for agricultural purposes may be estimated at not less than four times this quantity, or 12,000 cubic feet per second. There are, of course, periods when the volume of the river is far greater than this latter amount; but for practical ends, and as measures of the capacity of the stream for irrigation, 3,000 and 12,000 cubic feet per second may safely be assumed as the constants of discharge during the dry and wet seasons respectively, and I will so employ them throughout this paper.

The fall of the river bed is most irregularly distributed; that of the country forming the banks, on the other hand, is very regular from the highlands on the northward down to the sea coast. The stream breaks through the highlands just referred to at a place named Palaveram, and the surface of the country there is 80 feet above the level of the sea at high-water spring tides. The difference of summer and monsoon levels of the river's surface is, at the same place, 38 feet. Hence the summer level is only 42 feet above high-water mark, there being, of course, no rise and fall in the water's surface at the junction of the river with the sea. The total distance from Palaveram to the ocean is 60 miles in a direct line, and the uniform fall of the summer surface measured thereon is therefore very nearly $8\frac{1}{2}$ inches per mile. But no such regularity exists in fact; for Colonel Cotton mentions that in one series of surface levels taken by him, he found a fall of 9 feet in 3 miles, or 3 feet per mile; in another $1\frac{1}{2}$ feet in 4 miles, or only $4\frac{1}{2}$ inches per mile. The same irregularity marks the distribution of the levels of the river bed. There are fords at various points on which the summer water stands from 3 to 4 feet deep; but between these shallow spots there are extensive pools measuring from 26 to 30 feet in depth. Taking the entire length of the river channel into account, the effective fall of the bed is not more than from 5 to 6 inches per mile.

The high flood surface level is distributed with much greater uniformity; though, from the extreme irregularity of the bed, the rise and fall of the high freshes is subject to certain anomalies, decreasing, however, on the general average as the coast is approached. As illustrations of this fact, it may be mentioned, that the difference between the summer and monsoon level at Palaveram is 38 feet; 20 miles lower, or at Rajahmundry, it is 31 feet; at the head of the true Delta, 4 miles lower, it has fallen to 27 feet; while 11 miles lower down the same height is still maintained. All these are the results of local causes dependent on the form of the river bed and dimensions of channel; but for our purposes it will be sufficient to note that the high flood surface level of the river falls towards the sea at an average rate of from 15 to 18 inches per mile.

The surface of the country on the right and left banks of the river falls with great regularity towards the coast. Above the head of the Delta at Dowlaisweram, the general fall may be estimated at 18 inches per mile; and below that point the average rate decreases to 12 inches. These details will illustrate sufficiently the longitudinal section of the Delta, in the direction of the river's course.

But there is still the characteristic feature of Deltaic rivers, in the transverse slope from the central ridge on which the stream runs, to be noticed; and in the case of the Godavery this is still more prominent, and still better adapted to the purposes of artificial irrigation than we have yet found it to be either in the case of the Cauvery or the Kistnah.

The fall of the country on the right bank towards the east, and of the left bank towards the west, is much more rapid than that towards the sea. By sections taken below the point at which the Godavery leaves the hills, it would appear that both on the east and west banks this transverse slope is equal to 12 feet per mile. At the head of the Delta the fall is diminished to 3 feet per mile on the east, though continuing at 8 feet per mile on the west; while again, at only 25 miles from the sea, the slope is still equal to nearly 4 feet per mile. Hence, then, the river runs on the crest of a great natural embankment, ranging from a minimum of 6 feet to a maximum of 24 feet in height above the level of the country, 2 miles distant on each bank, and it is scarcely possible to conceive an arrangement better adapted for facilitating artificial irrigation works than this.

The problem accordingly presents itself to us in the following clear and readily comprehensible shape. Given, a river with levels relative to the country through which it flows, like those just described for the Godavery, to determine—first, the height of a Dam at the head of the Delta, which will give us an efficient command over the whole irrigable surface of that tract; and second, the extent of deep channels sufficient to deliver the water of irrigation on the surface of the land. The solution of the problem under the conditions described is by no means a difficult one.

At the site which natural circumstances have marked out as the best for a Dam or Annicut, viz., the head of the Delta proper at Dowlaisweram, the deep bed of the river is nearly 22 feet above high water mark. The highest portions of the Delta for which irrigation has to be provided from this point, excluding the ridge on which the river runs, are not more than 30 feet above the same level. An elevation of the deep bed of only 8 feet would therefore place it on the same general level as the land to be watered, and in many places above it. An additional height of 3 or 4 feet would give a perfect command and establish a working and most efficient head of water, which would make irrigation a matter of the greatest facility over the whole surface. Hence, then, a Dam or Annicut 12 feet high established at Dowlaisweram, would fulfil the first condition specified in the preceding paragraph. The second is determined by the following conditions:—To be rather above than below the truth, I will assume that the height of the high banks of the river at Dowlaisweram is 30 feet above the deep bed, and consequently 18 feet above the level of the sill of the proposed Dam. On the west bank the transverse fall from the river onwards is 8 feet per mile. Hence, a channel of irrigation, with its bed on the level of the sill of the Dam, and carried out without fall, would strike the general surface of the country at only $2\frac{1}{4}$ miles from the river bank; and if a slope of 12 inches per mile were given, the distance would be increased only to $2\frac{1}{2}$ miles. To this short distance, therefore, the heavy excavation at the head of the channel would be restricted on the western side. On the eastern the case is not quite so favorable. Here the country falls outwards from the river at the rate of 3 feet per mile; and hence, a channel carried out like the preceding on a dead level, would crop out on the surface of the land at 6 miles from the head, and if a slope of 12 inches per mile were given to its bed, the distance would be increased to 8 miles. On both banks, however, the maximum distance—during which the water would be below the surface of the land—would be no more than $10\frac{1}{2}$ miles, and on this the mean depth of digging would not exceed 10 feet, while the maximum would be 18. The natural conditions of the river are therefore most encouraging, and the professional difficulties were never such as to oppose any serious obstacle to the success of the design. Experience in Tanjore had most satisfactorily demonstrated the practicability of executing and maintaining such works as the required Dam under circumstances more trying to such structures than those of the Godavery, and though it seemed at first sight a truly formidable undertaking to bar a river fully 8 times the breadth of the Mississippi, and subject to floods rising from 27 to 28 feet in height above summer level, yet when examined closely the difficulties became very manageable, requiring neither great expense nor unusual skill to overcome them.

Immediately above the line selected for the Dam, the Godavery is 2,000 yards in width; at the site itself the width expands to 6,000 yards, or nearly 3½ miles—about 1,000 or 1,500 yards being occupied, however, by islands dividing the main stream into several separate branches. In the immediate vicinity abundance of stone and hydraulic lime suited to the purpose of building in water is found; labor is exceedingly cheap in the adjoining districts; the soil of the river bed is in no way inferior to that dealt with on the Cauvery and Coleroon rivers; while the velocity of the current to be contended against is that due to a slope less than a third of what obtains at the head of the Delta of Tanjore. The supply of men and material was therefore provided under circumstances most favorable to the economical execution of the work.

The next point that presents itself for illustration is the nature and extent of the land to be irrigated within the limits of the Delta. A line drawn through the eastern margin of the Colair Lake, may be regarded as the boundary of the Delta on the right bank of the river, while another line passing through Samulcottah bounds it on the left bank; within these limits the soil is described as "one noble expanse of rich alluvial land fit for almost any cultivation," and the only unproductive portion is a narrow sandy strip bordering on the sea. The areas of the separate portions are given as follows:—

East of the Godavery	450	square miles.
Between the two main Branches	550	"
West of the Godavery, and within the District of Rajahmundry	700	"
Do. do. do. Masulipatam do. to the Eastern border of the Colair Lake	300	"
Total irrigable area	2,000	"

If the Colair Lake itself and the land bordering it be included (and there is no reason whatever against this), the irrigable area would be increased by 500 square miles more, making the whole expanse subject to the Godavery irrigation equal to 2,500 square miles or 1,600,000 acres. A deduction of one-fourth of this for sandy tracts and waste land of various kinds would leave an effective area of irrigation equal to 1,200,000 acres. Now in the highest freshes it is calculated that the Godavery carries a volume of water sufficient for watering once over fully 90 times the area here given; but such freshes are only spasmodic occurrences, and the constant of discharge for irrigation, or that quantity which may be depended upon during the whole course of the crop, may be taken, as I have already stated, at a minimum of 3,000 cubic feet per second during the low, and 12,000 during the high period of the river's volume. On these data our estimates of work to be done must accordingly be founded.

During the months of July, August, September, and October, the higher quantity may be depended upon. These are the months when the great staple of the country, the rice crop, is in the ground, and requires a constant supply of water to bring it to maturity. According to the constant of area irrigated employed in this paper—viz., 40 acres of rice to 1 cubic foot per second of water — the Godavery is competent to the irrigation, during its high period, of 480,000 acres of that grain. During its low period, again, it is competent to the irrigation of a certain extent of sugar-cane, estimated by Colonel Cotton at 100,000 acres. But in this there must, I think, be some mistake; for looking to the hygrometric conditions of the sea-coast region of the Godavery irrigation, and of the dry inland tracts of the Northern Doab, it seems scarcely probable that a cubic foot per second of water would do so much less work in the former than we know it to do in the latter, when applied to precisely the same article, namely the sugar-cane. The constant of area irrigated with that crop in the canal districts of Northern India, is estimated at 119 acres for each cubic foot per second of discharge; but taking it at only 100 acres, the volume of the Godavery at its minimum would be enough for the full irrigation of 300,000 acres of sugar-cane. Rice requires fully 3 times the quantity of water sufficient for sugar, and unless there are circumstances of which I am ignorant, serving to change the ordinary relations of the two products in reference to irrigation, I cannot see why the Godavery works should not have full credit given them for the work which I believe them competent to perform.

Hence, then, the total area for which water is permanently available amounts to 780,000 acres, and as the irrigable area of the entire Delta has been estimated at

1,200,000 acres, it appears that very nearly two-thirds of it are capable of being actually watered, leaving only one-third for dry cultivation or dependent on the rains. These proportions raise the Delta above the highest class of irrigated tracts existing at present either in Northern Italy or in Northern India, and give fair promise of an ultimate condition of agricultural prosperity equal, if not superior, to anything which has yet resulted from works of irrigation in this country. I shall have a better opportunity, hereafter, of alluding to the actual money returns to be anticipated from the Godavery works, and may now pass on to a general description of these works themselves.

There are four classes of works required to raise the Delta of the Godavery to the highest degree of productiveness of which it is capable. These are—

First.—Works of irrigation proper, being Dams and attached channels whereby the water would be delivered on the surface of the country at efficient levels.

Second.—Works of drainage, being channels of escape for the surplus water of floods or irrigation thrown over the surface of the country at inappropriate seasons, or likely to stagnate for excessive periods.

Third.—Works of protection, being embankments to the river channel sufficiently high to prevent the monsoon floods swamping the crops, and generally devastating the low tracts by annual inundation.

Fourth.—Works of communication, being navigable channels wherever they can be obtained, and roads sufficiently embanked and bridged to preserve the cross communication during the rainy season.

At this present time none of these series are perfected; but the three first are in active progress, and have already led to satisfactory results. As regards the fourth, a large extent of navigable channels fitted with locks exists, but no raised roads have yet been commenced, and till they are carried to such an extent as to make transit practicable during the rains, the Godavery Delta will continue to be inferior to that of the Cauvery, the latter being abundantly supplied in this particular way.

In describing the works of irrigation, the first and most important, as being that on which the whole system rests, is the Annicut, or Dam, across the Godavery at Dowlaisweram, about four miles below the town and station of Rajahmundry, the capital of the district of the same name. I have already had occasion to remark, that at this point the stream becomes subdivided into several channels by the intervention of islands, or as they are locally termed "Lunkas."* The number of these channels is four, and across each a separate Dam has been constructed on the same general plan, and only with slight variations of dimensions. This subdivision of the stream was of special advantage during the construction of the works, as it admitted of the river supply being diverted entirely from each

* These "Lunkas" are locally famous for the tobacco they produce, and give name to a peculiar form of cheroot much affected by Madras men. I must have been unlucky in my trials of them, for they seemed to me intensely acid and coarse in flavour, reminding me of the long thin black and most potent cigars native to Lombardy, and with which most travellers in that part of Italy have made personal acquaintance perhaps, like myself, to their own discomfiture.

channel in succession into the others, and of the masonry being built accordingly with little or no annoyance from leakage. The bed of the river is throughout of pure sand, and in such soil are the whole of the foundations laid.

Commencing from the eastern or left bank, the first portion of the work is the Dowlaisweram Branch Annicut or Dam. The total length of this is 4,872 feet, or 1,624 yards. The body of the Dam consists of a mass of masonry, resting on front and rear rows of wells, each well being 6 feet in diameter, and sunk 6 feet below the level of the deep bed of the stream. The masonry forming the body is composed—1st, of a front curtain wall running along the whole length, 7 feet in height, 4 feet in thickness at the base, with footings one foot broad on each side to cover the tops of the wells on which the curtain wall rests, and three feet thick at the summit; 2nd, of a horizontal flooring or wasteboard, 19 feet in breadth, and 4 feet in thickness; 3rd, of a masonry counterarched fall 28 feet in breadth, and 4 feet thick, of which the curve is so slight, that the form may be considered practically as that of an inclined plane. The wasteboard and tail slope are protected against the action of the stream by a covering of strongly clamped cut stone over all; 4th, of a rough stone apron in rear formed of the most massive stones procurable, and extending about 70 or 80 feet down stream. This protects the rear foundations against the erosive action of the stream passing over the Dam, and will be extended as circumstances may require. The body of the Dam rests merely on a raised interior embankment or core of the common river sand, and no precautions to strengthen this in any way have been considered necessary. On both flanks masonry wing walls and revetments connect the Dam with the main land on one side, and the island No. 1 (I dispense as much as possible with proper names, as they are so very unpronounceable) on the other, thus obviating the risk of the works being turned by the river in flood.

On the extreme left flank of the Dam is a series of works, consisting of a lock for the passage of craft, a head-sluice for an irrigation channel, and an under-sluice for purposes of scour and clearance from deposits. The first has a chamber 100 feet in length, and 15 feet in breadth, with a drop of 12 feet, and fitted with all the machinery in gates and sluices required for effecting its objects. The second or irrigation sluice has 13 vents of 6 feet each, thus giving a clear water-way of 78 feet. For purposes of cross communication and approach to the Dam proper, the small arches of the vents are surmounted by 3 large arches of 33½, 40, and 33 feet in span respectively, carrying a roadway of 16 feet in width, between the parapets; and the flanks of this upper bridge are secured by massive wing walls strengthened with counterforts. A line of revetment wall 157 feet in length, also supported by counterforts, and protected in front from the action of the current by a semicircular mass of rough stone projecting up stream like a huge bridge starling, and having a radius equal to half the length of the wall, or 78½ feet, connects the head and under sluices. The general disposition of both as regards roadway and vent arches is the same; but the under-sluice has three of the former, of equal spans of

42 feet each, and 15 of the latter, having each 6 feet span. The clear waterway for scour is therefore 90 feet. For minute professional details of these various works, I would refer to the plans accompanying this report, in which they are all very fully exhibited.

On the right or island flank the upstream revetment is carried $297\frac{1}{2}$ feet into the solid soil, and on the downstream side the corresponding work has a length of $87\frac{1}{2}$ feet. From the termini of these masonry lines, a substantial earthen embankment is carried right across the head of the island till it impinges on the flank protections of the Dam across the second branch of the river.

This is called the Rallee Branch and is barred by an Annicut or Dam 2,862 feet, or 954 yards, in length. In section, this work differs a little from that just described. The general dimensions of the bodies of both are similar; but the front curtain wall of the Rallee Dam, instead of resting on a row of wells, is founded on a mass of rough stone, and this mass extends under the wasteboard or sill, and part of the curved tail, thus replacing the core of river sand characteristic of the Dowlaisweram Branch Annicut by one of a more substantial kind. The rear foundations consist of a row of 6 feet wells as before; and the only difference in the rough stone rear apron is the insertion along its length of a retaining or bonding bar of masonry 4 feet in breadth by 3 in depth. The left flank revetments are similar, though not quite so long as those formerly described. On the right flank is an under-sluice with eight small vents of six feet each, and two large arches carrying a roadway for cross communication.

The subdivision of the main stream of the Godavery into four channels at Dowlaisweram is not permanent. Islands No. 1 and 3 are small, and below them the four channels reunite and form two, whereby the waters of the river are finally carried to the sea, and which, under the names of the Eastern and Western Godavery, bound a large tract of rich alluvial land, on the head of which the right flank of the Rallee Annicut abuts. For the irrigation of this tract, said to be the most fertile throughout the Delta, adequate provision has been made by a head-sluice constructed on the land, intermediately between the Rallee and next adjoining branch, the Muddoor. This sluice is similar in its general plan and dimensions to that of Dowlaisweram, but with 60 feet of waterway* disposed in ten vents of 6 feet each. On the left flank of the head there is a lock for the passage of craft into the channel. A strong earthen embankment runs as before quite across the head land, linking the right flank of the Rallee with the left one of the Muddoor Branch Dam, to which we may now advance.

The length of this, the third section of the great work, is 1,548 feet, or 516 yards. Its section is precisely the same as that of the Dowlaisweram Dam; it has the same front and rear foundations on wells, the same dimensions of the masonry body, which rests on a like core of river sand without any intermixture of heavy material. Its up and down stream flank terminations

* The plans are not clear in this particular, and I am not quite certain whether the waterway consists of 8 vents or 10, but I have presumed the latter The plans seem to show 9, but the scale is so small that I infer there is a slight error.

are further the same, and it has neither head nor under-sluices attached to it. The usual earthen embankment stretches across the head of island No. 3, and is terminated by the left flank abutment of the Vegaishweram Branch Dam, the last of the series.

The length of this portion is 2,584½ feet, or 861½ yards. In section it presents several small differences from any of the others: its height at the sill is one foot greater than the others; the thickness of the masonry of the body of the Dam 6 inches, the breadth of the sill 3 inches, and that of the tail 9 inches more than the corresponding details for the other portions. The foundation and core of sand within the body are like those of the Dowlaisweram and Muddoor Dams, but the front curtain wall is protected by an apron of rough stone about 10 feet deep, and 6 or 7 wide, carried along its entire length. The rear rough stone apron is banded and strengthened at 20 feet from the termination of the masonry tail by a bar of stone in mortar 6 feet wide by 2½ feet deep. With these differences in detail, the general arrangements are the same as in the other branches. *It was impossible for me to look at the* set of the current above the Dam, and not see that the Vegaishweram Dam was the weak point of the entire structure, and that which must be watched with the greatest possible care, and protected with the utmost caution to guard against a breach. The main force of the stream was thrown directly upon it; cutting of the protective banks was in progress, and some accidents had already occurred to the works, which had been accepted as warnings, and had led to vigorous measures of precaution to divert the stream and divide its force. The right flank terminations are the same as before; and the ordinary embankment is carried across a small island, No. 4, formed by the branch and a mere channel, across which a bridge of communication, having vents corresponding in number and position to those on the left extremity of the Dowlaisweram Dam, is carried, and connected on its right with an irrigation head for the supply of the western portion of the Delta. The series of works on the right main land is completed by a lock of the ordinary form and dimensions for admitting river craft into the western channel.

Viewed as a whole, therefore, the Godavery Annicut consists of a masonry Dam in separate portions, the united length of which is 11,866½ feet, or 3,955½ yards, being very nearly 2¼ miles of river channel blocked up by a solid, substantial, well-protected mass of stone in lime cement, or without it, according to position, having a total breadth of base equal to very nearly 130 feet, and height of crest or sill equal to 12 feet.* The three main objects of the Dam—clearance, irrigation, and transit—are provided for by three separate sets of works, one on each mainland flank, and one at the head of the central tract. The under-sluices discharge the necessary functions for the first object, the head-sluices those for the second, and the navigable canal and locks those for the third. Along the entire length of the masonry Dam is carried a line of cast iron uprights about 6 inches square, and 8 or 10 feet apart, having grooves on each side for the reception of 2½ feet of planking,

The separate masonry portions are connected by earthen embankments, between six or seven thousand feet in length, and protected at the junctions by fully 2,500 feet in all, of masonry revetments.

whereby the water can be retained to that height above the sill during the dry season, and a larger volume be thus thrown into the irrigation heads.

This last arrangement is one to which serious objections have been expressed; and as the projecting uprights form impediments to the free flow of the water over the Dam, and may cause rubbish of various kinds to collect around and between them, these objections are not unreasonable. With rivers such as those on which my experience has been gained, I would certainly have preferred raising the whole sill of the work; because we have enormous masses of the sweepings of forest-covered regions, in the form of trunks and branches of trees, grass, and other jungle products, to deal with, which accumulate in front of even slight impediments in all stages of floods, and expose the works to very formidable risks. But if it be true, as I am informed, that the Godavery is never charged with such materials except when the floods are at their greatest height, or near it, I cannot conceive that any serious danger is involved in the use of the iron uprights and planking; especially as the latter would always be removed in anticipation of floods, and only the former left in the Dam. I shall not be surprised to hear at some future period, however, that it has been determined to add 2 feet to the permanent height of the Dam, and to maintain its wasteboard clear of all impediments.

I have formerly expressed my conviction that nothing more than merely local action on the river bed can be anticipated from the influence of the under-sluices; and experience at the Godavery Dam has already confirmed this belief. The whole river bed in front of the work is steadily rising: it is now, judging from the sections before me, within $1\frac{1}{2}$ or 2 feet of the crest; and it will inevitably go on progressively until that line is reached, and a new adjustment of the deep bed on the up-stream side will then be complete. In the immediate vicinity of the sluices a clear channel will be maintained, with a depth dependent on the amount of the depression of the floorings of the vents beneath the crown of the Dam, and of this the irrigation heads adjoining will have the benefit; but whatever contingencies are to be anticipated from the certain effect of the main work on the general level of the bed northward of it, should be fairly looked in the face and provided for by the appropriate arrangements. The only one of any real consequence is the elevation of the surface of the water in floods, and the risk of inundation. It will still be a considerable time before the whole extent of the deep bed, under the influence of the Dam, can be so much affected by deposits as to lead to serious consequences; and there is therefore abundant time to study the matter, and to construct such embankments as may be required for the protection of the country on both banks, as the necessity for them may become apparent.

In speaking of the Locks attached to the Kistnah Dam at Bezwarah, I took occasion to refer to what seemed to me objectionable in their position, and mentioned that at the Godavery my own observation had satisfied me that the dangers to the works themselves, and the craft using them, were real. When I saw the Vegaishweram Lock on the right mainland flank of this work, it was in utter ruin: the adjoining bridge had been seriously damaged, a large boat had gone down, and the general aspect of things was certainly not satisfactory at that particular place. Nor have I reason to believe that the action of the other Locks was much more perfect: they are used, if used at all, with timidity and doubt, and will never fulfil, as they ought to do, the object of their construction, until they are removed from their present localities, and relieved from the excessive force of current to which they are exposed. I was told that, with *proper precautions*, they might be used, and possibly this may be true; but to meet the wants of the native community, even what an educated European officer considers *proper* precautions must be dispensed with, for they will never be observed by men so habitually careless, and constitutionally inert, as the low class for whose use these works are designed. The experience of the present season (1853) has added force to previous observations; and I venture to hope that no mistaken views of economy or attachment to preconceived notions may interfere to prevent the arrangements for internal navigation being made as complete, as safe, and as easy of use as possible.

I have not attempted to enter into any details of actual construction, or of the various means whereby labor was economized in the collection of materials, or otherwise; but I cannot leave Dowlaisweram without at least a brief allusion to the machinery in operation to these ends. The place had the aspect of a busy factory on a great scale. Within the workshops a steam-engine was driving various kinds of machines employed in wood and iron work. A second steam-engine was in progress of construction, of which it was hoped that every part of the machinery would be made on the spot. An iron foundry was in active operation, and with considerable success. Outside, sheet-iron boats, to be fitted with engines and used as steam-tugs, were being made; and already three such boats were in active operation on the river, towing barges laden with wood, stone, or other building materials, from the mainland to the islands; a fleet of sailing boats was also in use for similar purposes, and the whole was under command of an European officer, who had served in the navy. The connection with the quarries and the bank of the river was maintained by a short railroad, and a line of navigable canal, fitted with several ingenious contrivances for facilitating transit in shipping the huge stones, and otherwise. The workshop and material departments were by no means the least interesting connected with the works, and the whole arrangements were highly creditable to Captain Hutchinson, of the Madras Artillery, the officer in general charge of the machinery. The only other notability connected with the works brought under my observation, was the native superintendent, Veeranoo, to whose energy and ability Major Cotton drew my especial attention, by saying, that without him he doubted whether the undertaking would have been completed for years to come, and certainly could never have been finished, as it has now been, with scarcely a serious check, and without an important accident. It is no reflection on the officers concerned to say, that when I wanted any minute detail likely to have escaped everybody's memory Veeranoo was sure to have it ready for use at a moment's notice; and I have rarely—I may say, never—

met a native whose intelligence was more remarkable. I hope he has still a long life of usefulness before him.

Having thus described, in general terms, the main features of that central work on which the Godavery irrigation system rests, I may now proceed to notice, in the same way, the local details of distribution channels, and such other points as are necessary to complete the view of the entire scheme.

In doing so, it will be convenient to sub-divide the Delta into those main sections, the boundaries of which are well defined by natural lines, while the irrigation of each is provided for by specific works. These sections are:—First, the Eastern, bounded on the left by the limits of the Delta, of which Samulcottah may be conveniently taken as the extreme point, though it is proposed to push one channel beyond it. The right boundary line is formed by the Eastern Godavery. Second, the Central Section, being the tract included between the eastern and western branches of the river. At about 15 miles from the coast, the Western Godavery throws off a large branch, which, after a very tortuous course, joins the sea by a mouth of its own. Between this minor and the great main branch on the west, is included a very rich tract of land, for the irrigation of which special provision, to be described hereafter, has been made. Third, the Western Section, bounded on the east by the Western Godavery, and on the west by the Colair Lake and country, forming the connecting link with the Delta of the Kistnah. The irrigation channels in each of these sections may be noticed in the order of succession thus given.

The general idea pervading the plan for distributing the channels of irrigation has evidently, if I may judge from the maps before me, been to carry along the banks of each main branch of the river longitudinal eastern and western channels, and to carry out from these, on both hands, such number of transverse channels as the necessities of the country required. There is a manifest propriety in this arrangement, for it will be borne in mind that I have described the river as occupying the crest of a ridge, which is elevated from a minimum of 6 to a maximum of 24 feet above the country two miles distant from it. Hence the transverse channels have the full advantage of this command, and distribute the water with admirable effect.

These transverse channels, however, are not necessarily connected with the longitudinal ones; but when occasion requires, are projected directly from the head-sluice into the adjoining country. In accordance with the general plan, the irrigation of the eastern section of the Godavery Delta is provided for—1st, by a main longitudinal channel, following the course of the left bank of the river from the head at Dowlaisweram to a point about 25 miles to the southward. It is proposed to prolong it about 10 miles farther, and then to connect the tail with one of the numerous natural channels in the neighbourhood, through which the surplus water will find an escape to the sea. 2nd, by a main and independent transverse channel, which at four miles from the Dowlaisweram head separates into two principal branches, one directed upon Samulcottah and capable of prolongation to an extent only limited by the available supply of water, and the other directed upon the Port of Coringa—the best harbour between Calcutta and

Madras, and a place that is not known and appreciated as it ought to be, simply because its whole history is one of neglect and indifference. This latter channel is one of the highest importance to the prosperity of the Delta: it links the Godavery with the sea at a most favorable point by a line of internal navigation adapted for the largest form of native boat in use; it is provided with three sets of locks for overcoming the surplus fall; its current is moderate, its volume sufficient or capable of being made so, if it is reserved for navigation alone, during nearly the whole year; and its course is quite direct between its two terminal points. At a place called Chintapilly the Coringa line throws off a minor channel on the right for irrigation. The total length of these independent transverse channels into which water has already been admitted is 75 miles, and a farther length of about 50 miles is either in course of execution or projected. 3rd, by a series of transverse channels having their heads on the main eastern line, and deriving their supply from it. Of these, one only, with a length of about 20 miles, has as yet had water in it; but nearly 100 miles more are marked out, and are either being carried on or will shortly be commenced. Of this series, three are directly connected with the eastern river bank channel, while five others are thrown off from the transverse channels themselves. There is, therefore, either actually provided, or in accordance with existing plans, to be hereafter provided, for the irrigation of the eastern tracts, a length of main channel of about 220 miles from which water will be supplied to village channels to an extent dependent on the available supply of water.

This supply, during the season of the rice crop, will be equal to 4,000 cubic feet per second, *i. e.*, supposing an equal distribution of the estimated permanent volume of the river to be made among the three tracts of the Delta, and the total irrigated area will, with the usual data, amount to 160,000 acres, or nearly three-fourths of the superficies of the eastern tract—a prospect certainly of the most encouraging kind. The equable distribution of the supply would probably, however, not be the best; but on a matter of mere detail like this it is not necessary for me to occupy time and space. It is quite sufficient to make it clear that east of the Godavery 160,000 acres of rice land may be cultivated annually, if it should be expedient to carry this culture to such an extent. If it is not, there is an ample field for the consumption of the water in other portions of the country, and neither Government nor the agricultural portion of the community need lose a drop of it uselessly. During the summer 1,000 cubic feet per second would be at command in this region if required, and such a volume of water would suffice for bringing to maturity a sugar crop on 100,000 acres of land.

The central tract of the Delta consists, on a rough estimate, of 352,000 acres, lying between the two great branches of the river, and characterized by a rich alluvial soil of surpassing fertility. For the irrigation of this area a main channel leaves the Rallee head at the Annicut, and after a course of about 8 miles, divides into a right and left channel, each following the general direction of the branch stream nearest to it. At about 6 miles from the point of separation, the right channel is again subdivided, throwing off a smaller line, which is carried across the minor branch of the Western Godavery, formerly alluded to, and furnishes a supply of water for the irrigation of the tract between these branches.

The passage of the branch is effected by means of the Gunnarum aqueduct—a work most creditable to the professional character of Lieutenant Haig, of the Madras Engineers, the officer by whom it was constructed. It will be convenient to give a short description of it here. The total length of the aqueduct, between abutments, is 2,248 feet, divided into 49 arches of 40 feet water-way each at the springing of the arches, and 48 piers of 6 feet in thickness at the same points, with an external batter of 6 inches on each side. The abutments on both sides are segments of circles, having radii of 35 feet terminating in return walls, binding the work into the embankments of the channels 15 feet in length each. These and the piers rest on wells $5\frac{1}{2}$ feet in diameter, and sunk 8 feet deep in the sandy bed of the stream. Over the well-tops is a flooring which, in 25 arches, is composed of concrete, strengthened by 5 bond-walls of bricks 2 feet in breadth. The flooring is 1 foot thick and is supported by 5 rows of wells, 4 feet in diameter, and sunk 3 feet in the sand beneath, the heads being secured by the bonds just alluded to, which run through the whole length of the flooring. The total height of the piers from the floor to the springing-line of the arches is $11\frac{1}{2}$ feet, the rise of the arches 7 feet, their thickness throughout $2\frac{1}{2}$ feet; the height of the parapets above the line of the crowns of the arches is 6 feet, and they are surmounted by light wooden railings $3\frac{1}{2}$ feet in height. The top of each parapet is made to carry a foot pathway 6 feet in breadth for purposes of cross communication. The spandrils are not filled in; there is no flooring to the aqueduct channel between the parapets, which are 2 feet thick at top and 3 at bottom, with spandril walls 1 foot thick and of lengths variable according to their position. The water thus flows over an exceedingly rough bed, and when I saw the work there were several awkward rapids at different points of its length. There is a fall of 2 feet from the eastern to the western end, which is nearly at the rate of 5 feet per mile, causing great rapidity of current. The breadth of the channel varies a little, ranging from 22 to 24 feet. Loose stone aprons protect the foundations in front and rear, and they will be extended as occasion requires. The architectural design is perfectly plain and hard—in fact, the elevation is merely that of a wall with a series of holes through it, and its appearance is even heavier than there was any occasion for making it. The whole structure is of brick in excellent cement—the bricks being unusually large, or 18 in. by 6 in. by 3 in. To facilitate their being burnt in kiln, the length of each brick is traversed by a small circular hole half an inch in diameter. The results of this were so satisfactory, that on my arrival at Roorkee I suggested its being tried in bricks of the same size required for the Ganges Canal works, and the experiment has proved very successful—the material being burnt perfectly throughout its entire bulk. The little hole in the centre of the brick seems to act as a conduit-pipe for the heat and an escape for the moisture, so that the action of the fire generally is more complete. At first the moulding of the bricks required a longer time, but with experience this difference has almost disappeared, and the facility with which material so much above the average bulk can be now supplied fully compensates for the little difference that remains. For farther and more minute details of the work I would refer to the plans.

The average capacity of the channel of the aqueduct, with 4 feet of water, a slope of 5 feet per mile, and a mean breadth of 22 feet, may be estimated at very nearly 500 cubic feet per second; but on emergencies it is of course possible to force from 100 to 150 feet per second more through it without any very formidable risk. Taking the discharge for full irrigation at 650 feet, the irrigated area would be 26,000 acres, supposing rice to be cultivated exclusively; the total area of the tract is approximately about 60,000 acres, and the culturable area may, therefore, be estimated at about 45,000. Considerably more than half of this might accordingly be placed under wet cultivation, leaving the remainder dependent on the rains or the accidents of the river supply. This proportion is superior to any of our canal districts on this side of India, and is amply sufficient for the ordinary wants of the community.

It is a point worthy of note, that the whole of this great work was completed in three months from the date of its commencement. Materials had been accumulated, immense working parties collected from the adjoining districts, and every preparation made beforehand. The water was then turned off into the Western Godavery by the requisite embankments; and communicating his own energy to the whole establishment under his control, Lieutenant Haig virtually completed the aqueduct within the period I have mentioned. I must not conceal the fact, however, that this speed was paid for by a prodigious excess of expenditure on the original estimate, amounting to close upon, if not quite to, 100 per cent. The officers on the spot maintained that there was real economy in this apparent extravagance, but the Government had very naturally been startled by its occurrence, and the matter was in active discussion during my visit to Madras; but how it has been settled I do not know, and it would require a much more intimate knowledge of the accounts than I have to warrant any decided opinion whatever on such a matter.

It is impossible to consider attentively the circumstances under which the Gunnarum Aqueduct is placed, without having the question of its permanent stability forced upon one's consideration. It is unquestionably exposed to great risks. It seems to be possible to secure foundations on the rivers of Southern India, with their very low slopes, by means which, with our own experience of the rivers of Northern India, we would be justified in pronouncing utterly inadequate, and with which, in fact, we would never dream of operating, since they would inevitably fail on the first serious trial. I therefore conclude that, so far as the foundations are concerned, previous experience in other and similar localities is sufficient to warrant their being pronounced trustworthy. But the provision for the passage of the floods seemed to me inadequate. Within a few months (or possibly weeks, for I forget the precise date) after the aqueduct was finished, a flood rose, as I understood, not less than 5 or 6 feet over the level of the tops of the parapets, thus burying the whole structure under water. The height of this flood must have been about 30 feet, and it was no doubt an extraordinary one; but not so much so as to place it beyond the region of contingency, for which, in projecting such works, it is necessary to make some adequate provision. The sectional area of channel for such a flood, as provided by nature, is approximately about 72,000 square feet—that provided by the engineers is considerably over-estimated at 30,000 square feet. It is only necessary to look at the elevation of the aqueduct, and to note the proportion between the solid and permeable surfaces presented thereby to the stream, to make it self-evident how serious an obstruction to the current the work must be in all considerable floods, but especially in those where the flood-level rises high on the parapets. I must confess my own conviction to be, that this aqueduct will be a constant source of anxiety, and that the probabilities are in favor of the repeated occurrence of formidable accidents to it. That this anticipation is not imaginary has been proved by the experience of the past season; and I quote a few words from a letter, under date the 19th August, 1853, from an officer intimately connected with the works, showing that already the dangers to which the structure is exposed have exhibited themselves in a very serious form. "The great aqueduct, by the way, has received "considerable damage; the high and heavy side wall "having broken and fallen flat upon three of the "arches, which are thereby cracked considerably, and "one of them very badly. This was caused by very "high freshes, which came down at an unprecedentedly "early period. The Vegaishweram head-sluice (at "the Annicut or Dam) was also partly destroyed; "the ruins of its adjoining lock I believe you saw. "The Kistnah also rose to a prodigious height, and "flooded vast tracts in Masulipatam and Guntoor, so "that the people had to mount on the roofs of their "houses and on carts for safety. There was a regular "river, nine miles wide, north of Bezwarah, where "the land dips from the banks of the Kistnah."

I have added details not directly connected with the aqueduct, with the view of showing that the floods on this occasion were evidently paroxysmal, being rather grand *debâcles* of water than even freshes of the order termed extraordinary. I do not advocate perfect provision against such *debâcles*, for the expense would be enormous; and it is preferable, I conceive, to run the risk of such very rare events, and to be prepared to repair the injuries due to them, rather than to execute works which may not be required more than once or twice in a century, and the provision of which would prove, in all probability, a total bar to progress, by the gigantic scale of expenditure it would necessitate. It is because the aqueduct seems to me to be inadequate to its task of passing those high floods which often occur, that I have expressed the foregoing opinions; and though I have a high respect for its projector, it would, I conceive, be shrinking from my duty were I not to express them frankly. For occasional accidents, when such rivers as the Godavery are being dealt with, every reasonable person will be prepared, and will view them with due consideration; but it is to more than common risks that a work with the proportions of the aqueduct is exposed, and I see but little chance of the consequences being evaded while these proportions are maintained.

The levels of the country to be irrigated determine those of the channel; and in fixing the height of the crown of the aqueduct arches, the maximum elevation has apparently been given to them. No further relief could, I presume, have been given to the floods, by raising the channel level higher, without leading to other contingencies not difficult to foresee. If the arches could have been dispensed with altogether, the thickness of the piers considerably diminished, and a straight channel substituted for the existing form, material relief would doubtless have been afforded. The case, in fact, seems to be one for the application of that description of aqueduct, on a large scale, which we have used here, on the Eastern Jumna Canal, for many years past, on a moderate one, and are to use hereafter on the Ganges Canal in a very extensive way. Our aqueduct channels are straight sheet-iron tubes of the adequate dimensions, supported by light masonry piers. We have as yet made them only from 30 to 40 feet in length, and for volumes of from 80 to 120 cubic feet of water per second. But we shall extend them hereafter over the large rivers of the Doab, and six or seven years' experience justifies us in believing that no difficulties will be experienced either in constructing or maintaining them, and that the original expense will not exceed that of like works in masonry, while the repairs are of the most trifling cost. Whenever height over flood surface in rivers is important, these aqueducts have been found to act admirably; and I mention the idea here, because it may, perhaps, be useful under analogous circumstances in Madras, where, in consequence of the relative levels of floods and irrigating channel, the aqueduct must be occasionally submerged; by being beneath the former, it is not impossible that, by some mechanical contrivance, *the side walls of the channel might be* lowered on the flooring piece, and the obstructive effect thereby reduced to that of a thin plate. On details of this kind, however, it is needless to dwell, for there are many difficulties, unknown to me at a distance, which may make them inappropriate, and I therefore content myself with this general reference to the present point. I have only to add, with reference to the Gunnarum Aqueduct, that while I cannot regard its permanency as beyond question, no one will rejoice more heartily should subsequent experience prove my anticipations of accident to be unfounded, as none can admire more the personal energy and fertility of resource with which its progress has been marked.

To return now to the general distribution of the irrigation channels in the central tract of the Delta, I have to note that from the right extremity of the aqueduct a main channel is carried parallel to the Western Godavery, and close to its left bank, for a distance of about 15 miles. From this, transverse channels are carried into the interior, having a united length of 16 miles. These 31 miles are already in operation, and about 18 miles more are projected to complete the intersection of the tract between the western and its minor branch, with main channels. The village distribution will be carried on in the usual way. The total length of the western longitudinal channel, and its associated transverse lines from the Rallee Head, may be estimated at somewhat more than 90 miles.

The eastern longitudinal channel separates from the central line, as I have already mentioned, at about 8 miles from the Rallee head-sluice, and flows in an exceedingly tortuous uncomfortable-looking line (apparently the old bed of a nullah) to the southward, until it falls into the minor or aqueduct branch. This is the only channel in which water yet flows; its direct length is about 22 miles, but the extraordinary twists that disfigure it increase this to nearly 34. The projected lines connected with this channel consist of a principal one parallel and close to the right bank of the eastern Godavery, about thirty miles in length, throwing off a branch to the westward, and running well into the country about 18 miles long.

For the central tract, a total length of nearly 160 miles is accordingly provided by arrangements already contemplated; but these will doubtless be increased materially as the demand for farther accommodation of the kind arises among the people. Supposing the supply of water to be, as before, a third part of the available volume of the river, the surface irrigated throughout the tract would be 160,000 acres of rice and 100,000 acres of sugar, or nearly five-sevenths of the whole, which may be regarded as virtually the entire culturable area, since the two-sevenths left unprovided for would represent waste land in various forms for which no provision would be required.

The head for the irrigation of the last or western tract of the Delta is that before described as occupying the extreme right flank of the great Dam. From this point a main channel is carried out at right angles to the river's course for about 4 miles, and then turning due south, pursues its way for as much farther in a single bed. It then breaks off into several separate lines, the most easterly of which bears directly upon the right bank of the river, and on reaching it is carried on parallel to, and on its edge, for a distance of about 34 miles, when the tail is connected with the bed of the western Godavery. Connected with this longitudinal channel are others parallel and perpendicular to it which present nothing worthy of especial note, but the united length of which may be estimated at 120 miles.

The extreme western channel bears upon the Colair Lake, and is duly equipped with locks for the use of craft; it is nearly 40 miles in length, and connected with it are other channels, having a combined length of about 60 miles.

Throughout the 260 miles thus referred to, the water of the Godavery already flows, supplies irrigation, and facilitates navigation for the people between the western branch and the Colair Lake. To complete the network of channels, projected lines are marked out fully 200 miles more in combined length; and, when contemplated arrangements are perfected, there will be not less than 460 miles of main channel intersecting the western Delta in all directions. It is very clear from this that the equable distribution of the supply of the river which I have assumed, merely for the sake of illustration, will not hold good in fact; that if so great a length of channel is to be kept efficiently filled, a much larger volume must be assigned to the western than to the eastern and central tracts. Fortunately the latter, as I have already had occasion to show, can spare a considerable portion of their assigned supply, and yet be well provided for; so that there is no reason for anxiety on this point.

The total area of the western tract (exclusive of the Colair Basin), embracing the portions in the Rajahmundry and Masulipatam districts, may be taken approximately at 640,000 acres, and its culturable area at 480,000. Supposing it only to have the remaining third of the river supply, the irrigated area with that volume would be 160,000 acres of rice, and 100,000 acres of sugar as before, making a total of 260,000 irrigated out of 480,000 culturable, or about 54 per cent.—even in itself a large proportion, superior to that of our best districts in Northern India.

Viewing it comprehensively, therefore, the irrigation system of the Godavery consists—First, of the river itself, furnishing a supply for the rice crop of 12,000, and for the sugar crop of 3,000 cubic feet per second. Second, of the great Dam or Annicut at Dowlaisweram, whereby the above volumes of water are raised to a level sufficiently high to command the entire surface of the Delta, and of its attached works, whereby the passage of the supply is facilitated. Third, of 840 miles in all of main channels, whereby the water is distributed far and near over the irrigable area, and brought within command of every village in the Delta. The work which will ultimately be done by the machinery thus briefly described will be the perfect irrigation of 780,000, or considerably more than three-fourths of a million of acres of the richest alluvial soil. No one will question the noble proportions of such a project as this; and if it be carried on with earnestness and vigour, the most cheering anticipations may be indulged in regarding its results. It is still, however, far from complete; and in some of the particulars I have yet to notice, little or nothing has been done.

Irrigation is a process in agriculture of which regularity is an essential element. It is of very little use providing water for the land unless the same is given under command and control. But in a Delta, no such command can possibly exist, unless the river itself is placed under effective management; and hence, as I formerly mentioned, a judicious system of embankment forms an important feature in the general scheme of the works for the regeneration of that of the Godavery. The possibility of establishing such a system, without injury to the regimen of the stream, I hold to be perfectly proved by the success of the works in the Delta of the Cauvery, where they have existed, in greater or less detail, from the earliest historical period, and where they are in full operation at this moment, not only without producing the slightest injury to the river, but with the highest advantage to the prosperity of the country. The difficulties which presented themselves in dealing with the Cauvery and Coleroon were consequences, not of the river being embanked, but of that natural hydraulic law which ordains that the smaller in volume and less direct in course of two branches of one main stream shall always be liable to have its head silted up, and its capacity gradually diminished. Once this evil is corrected by artificial means, a proper provision of escapes and scours, such as I have described in the earlier portion of this report, have proved perfectly adequate to the maintenance in an effective state of the levels of the irrigating river. The Delta of the Godavery is in no way inferior, and in some respects superior, to that of the Cauvery; and I see no reason for hesitation in applying to the one the plans that have been so successfully practised in the other. So long as the floods are permitted to flow unchecked over the land, the irrigated crops must be insecure; and as these floods do not, even in extreme cases, rise very high above the natural banks of the river, their control is neither difficult nor costly. Colonel Cotton mentions that high flood may be taken at from 2 to 4 feet above the crest of the banks, and these dimensions give an idea of the nature of the works required. Strong embankments, each of which should be made wide enough to act as a roadway, and thrown back far enough on each side of the stream to leave a capacity of channel sufficient for the free passage of the river in flood, without any serious increase to its velocity by contraction of waterway, form part of the general plan. Every available point would be taken possession of for escapes connected directly with the sea, and all the resources that experience elsewhere has suggested for easing off the gorged channel of the river would be used. If the estimated height of flood level be correct, the embankments need nowhere be higher than 6 feet, and would generally be only 4; but on details of this kind I need not dwell, as they must be determined by local circumstances well known to the officers on the spot. Judging from the plans before me, it would seem that somewhat more than 200 miles of embankment will be required to complete the entire system for the protection of the Delta from inundation. A good deal of work has already been done, but more remains to do; and the object is so essential to the comfort of the people, and the permanent improvement of the country, that the operations will certainly not be allowed to halt in their progress.

General drainage, too, is being actively carried on; and for this there is great room, though there may possibly be occasional difficulties due to the irregularities of local levels. In roads and bridges, I believe, nothing whatever has yet been undertaken; but they, too, must take their place ultimately in the general scheme, and the sooner the better, both for the interests of the Government and those of the people.

The general impression left on my mind by my inspection of the Godavery works was on the whole very satisfactory. Though progress has not been rapid, it has been tolerably constant, and in the right direction. The causes of delay I shall have to allude to presently; but, in spite of these, much that was pleasant for a visitor like myself to look at had been accomplished. The spirit of the working officers under heavy discouragements was admirable; and if duly supported by the Government in the farther prosecution of their most valuable projects, I have not a doubt that every anticipation of success which has been placed on record, even by the most sanguine among them, will ultimately be realized.

In looking at the channels of the Godavery Delta irrigation, that exceeding irregularity of alignment, which was noticed in the case of the corresponding works on the Kistnah, inevitably arrests the attention. It was farther forced on my notice on my personal inspection of parts of some of the principal channels; and the views I have formerly expressed regarding this most objectionable feature in the works apply here with equal force. Economical considerations have doubtless led to the adoption of these old and tortuous lines, but I have no doubt as to what the final result will be. Just as in these provinces we are now abandoning, one after the other, the old alignments and straggling channels which our predecessors bequeathed to us, so, as water increases in value, and more land is brought under profitable occupation, will the present system on the Godavery Delta be given up, and perhaps wonder expressed that one so wasteful should ever have been adopted even as a temporary expedient. The home and local authorities have just sanctioned an expenditure of upwards of 1½ lakhs of rupees, or 15,000*l.*, on the construction of 25 miles of new channel for the Eastern Jumna Canal, expressly to get rid of those twists and low levels which the adoption of an old line entailed, and which have for years past led to great waste of water, heavy annual repairs, and, after all, great inefficiency of the works. The old line will now be abandoned, the whole of its works broken up, and a tract of the canal, on which not less than 2 lakhs of rupees, or 20,000*l*., have been expended in original works, will cease to exist—to the entire satisfaction of everyone concerned, whether on the part of Government or of the agricultural community. Far greater expenditure is contemplated in the rectification of the false alignments and levels of the Western Jumna Canal; and, as I said before, what experience has led us to do now might, with far better effect, be done at once, without any intermediate period, in the works of the Madras Presidency. The projected channels are generally unexceptionable in the particulars under review, and my remarks apply with effect to those in which the water is already flowing, and only to some among these.

I come now, in conclusion, to the least agreeable portion of my task—the review of the financial history of the Godavery irrigation. The uncertainty of engineers' estimates has almost passed into a proverb, and the present case is one which has given strong confirmation to the general impression. It is not that the excessive expenditure over the original estimate has been in point of fact either a recklessly wasteful or even an unreasonable one, but its influence on the mind of the Government has been almost as unfavorable as though it had been open to such imputations; and an amount of delay and difficulty in carrying on the works has been created by the disappointment of the original expectations which has been very prejudicial to the project. It was originally calculated by Colonel Cotton, in 1845, that the total expenditure for every kind of work required to place the Delta of the Godavery in a condition not inferior to that of Tanjore, would be

12 lakhs of rupees, or 120,000*l.*, distributed as follows:—

	Rupees.	£
The great Dam complete with Sluices, Locks, &c.	5,00,000	50,000
Embankments to the River	1,00,000	10,000
Irrigation Channels	2,00,000	20,000
Drainage Works	1,00,000	10,000
Sluices, Locks, and small Masonry Works	1,00,000	10,000
Roads and Bridges	2,00,000	20,000
Grand Total	12,00,000	120,000

And on this scale of expenditure the Government sanction was in the first instance given to the projected works. It was confidently anticipated that there was no probability of this amount being exceeded; and no language could be stronger than that on which this assurance was conveyed to the controlling authorities. The works were accordingly commenced at the great Dam, but they had not advanced far when it became evident that severe disappointment was in store for all connected with them. The elements of the original estimate turned out to be deceptive; the stone quarries from which it had been expected to obtain excellent material, proved to be bad, and prices had to be raised in proportion to the greater distances from which better material was necessarily brought; the quantity of stone required for the works had been considerably under-estimated; and lastly it was deemed expedient to adopt for the whole structure remodelled dimensions, giving it a more substantial and finished character, and constructing it in a better style than was designed at first. The combined effect of these different causes was, that in 1849, somewhat more than the total amount of the estimate had been spent while the work was scarcely half finished. At this point, the direct interference of the Government was most properly exercised by the appointment of a committee to examine and report on all that had hitherto been done, and to submit a supplemental estimate for farther expenditure on what remained yet incomplete. The committee examined the questions submitted to them in much detail; reported the causes of the failure of the original estimate to be generally as I have stated them above; recommended, however, that the project should be vigorously pressed forward to completion, as of its ultimate results there could be no reasonable question; and finally submitted their supplemental estimate, amounting to Rs. 4,07,506, or 40,750*l.* 12*s.* The expenditure previously incurred, amounted to Rs. 5,03,703, or 50,370*l.* 6*s.*, and an addition of Rs. 65,742, or 6,574*l.*, having been subsequently added to the amount of the supplemental estimate, as given above, on account of necessary extensions of the work, the total cost of the Dam was now estimated at Rs. 9,76,951, or 97,695*l.* It therefore appears that of the whole original estimate for the regeneration of the Delta, close upon five-sixths had been absorbed by the one main work required to raise the water to a sufficient height to be available for purposes of irrigation, leaving only one-sixth for the works of distribution, embankment, drainage, and communication, forming essential parts of the general scheme. For these, of course, new provision had to be made, and it is no matter of surprise, nor, I apprehend, should it be used under the special circumstances of the case, as ground of reproach to the local Government, that it should have expressed in strong terms its dissatisfaction at being led into an expenditure so far beyond that originally contemplated. It is unfortunate, however, that the want of confidence, thus created, should have been allowed to re-act, as it has done, on the progress of the works, and should have led to such reluctance in supplying the means of progress as has sometimes been shown. I cannot refrain from adding that the real interests of the Government are deeply involved in the effective completion of the various works, and that by every season that is lost or inadequately employed in carrying them forward, the state suffers in credit not less than in money, while the community is depressed and discouraged by their hopes of better times being constantly deferred. The disappointments of the past may now with propriety be forgotten, and the more cheering prospects of the future be dwelt upon.

These prospects are certainly most encouraging, and I may now give some illustrations of them. The present estimate of the whole expense required for the Delta improvements amounts to 24 lakhs, or 240,000*l.*; and, probably, if the works are carried out as designed, this will be sufficient. Up to the time of my visit in the spring of 1853, the total expenditure had been approximately about 15 lakhs, or 150,000*l.*, leaving 9 lakhs, or 90,000*l.*, for the work still remaining to be done. I doubt very much whether this sum will be sufficient to complete the whole scheme in the way it ought to be completed. It would certainly not be adequate to finish the whole, as in this part of India the Government expects all such works to be finished. The provision of the means of communication for the agricultural community alone, would absorb the whole of it, and more. Were we executing here 840 miles of main channel, we would consider ourselves bound to provide bridges for the common purposes of the community, not more than 4 miles apart (our fixed rule being to make the distance only 3) throughout the whole of this length, and such bridges would be quite irrespective of those on the high roads of the country. It was a matter of exceeding surprise to me to find that a provision of this sort was considered wholly unnecessary, and that in a country destined to become a busy scene of agricultural activity bridges for the use of the cultivators were wholly ignored. To dwell on the inconvenience to the people of such an imperfect system, in which a practical isolation of village from village is established by every branch channel, is needless, as it will suggest itself at once to every one; and fords, where such are practicable, or ferries, are very inadequate means of relief. In our distribution channels we give a bridge to every mile, but these are paid for by the people themselves, and they often spontaneously add to the number.

To allow for all probable contingencies—to admit of additions to the works having special reference to the comfort and convenience of the people—to give more extensive works for regulating and controlling the water in the channels than have yet been projected, a point in which existing plans seemed to me defective—and to prevent any likelihood of farther disappointment to the Government by unexpected excess of expenditure—

I would estimate the total probable outlay on the Godavery works at 36 lakhs of rupees, or 360,000*l.*; and to maintain them in perfect efficiency, I would estimate the annual expenditure throughout the Delta at $1\frac{1}{2}$ lakhs, or 15,000*l.*, which seems to me by no means an excessive, but only a liberal allowance. These two data, therefore, I will employ hereafter in my calculations of the returns.

In making such calculations, I cannot pretend to enter into minute revenue details. Nor is it either necessary or desirable to do so, as with incomplete information there must always be room for cavil in an affected detail. I will therefore state broad general facts, which, while they leave a fair margin for possible error, yet show results trustworthy and decisive under such an allowance.

It has already been estimated, that out of 1,600,000 acres, forming the entire area of the Godavery Delta, the irrigable portion may be taken at 1,200,000, and the portion for which water will be permanently provided by the works at 780,000 acres. We know from experience in Tanjore, what amount of general and land revenue a district, having such a proportion of wet cultivation as this, is able to pay with perfect ease to the community; and a better idea cannot be given of the ultimate influence of the Godavery works, than by comparing the present returns from the districts in which they are situated with those from the irrigated region of the Cauvery, it being borne in mind that in certain material respects the productive powers of the northern are superior to those of the southern Delta.

The area of the Delta of the Godavery, as above given, is situated partly in the district of Rajahmundry and partly in that of Masulipatam; the revenues of both are therefore affected by the proposed works. The greatest effect will doubtless be produced on the former, as the entire supply for its irrigation is derived from the Godavery, while the Kistnah plays an important part in the system for the latter. But for purposes of comparison it is necessary to take into account that portion of the revenue of Masulipatam which will be affected by the Godavery works, and though I cannot pretend to estimate this with rigid accuracy, I conceive that if I take it at one-third of the total amount, I shall be on the safe side. Hence, then, the whole revenue of Rajahmundry, and one-third of that of Masulipatam, has to be contrasted with the revenue derived from the Cauvery Delta.

Now the land revenue of Rajahmundry on the 31st of July, 1852, was Rupees 20,32,708, or 203,270*l.* 16*s.*, and one-third of that of Masulipatam on the same date was Rupees 3,75,052, or 37,505*l.* 4*s.*, making a total of Rupees 24,07,760, or say in round numbers 24 lakhs of Rupees, or 240,000*l.* The land revenue of the Cauvery Delta at the corresponding date, allowing for the whole of Tanjore, and those portions of the Trichinopoly and South Arcot districts which may properly be included in the Delta with the main tract, was, approximately, Rupees 43,46,851, or say 43½ lakhs, being 435,000*l.* The quantity of land for which an abundant irrigation is provided, is in very close relation, being in the Delta of the Cauvery 768,000 acres, according to the latest returns to which I have had access, and in that of the Godavery 780,000 acres. Wherefore, it clearly appears that while the one region, endowed with works of irrigation, yields to Government a revenue, from the land *only*, of 43½ lakhs, or 435,000*l.* per annum, the other gives at present one of but 24 lakhs, or 240,000*l.* The difference between these two returns, being 19½ lakhs, or 195,000*l.* per annum, is the fair exponent of the ultimate money return that will be derived from the Godavery works, when they have had time to develope their full effects upon the productive powers of the land and the energies of the people. I have estimated the original cost of the works, as I conceive, very liberally at 36 lakhs, or 360,000*l.*, and the annual outlay at 1½ lakhs, or 15,000*l.*; hence the net increase of revenue from the land would be, on the foregoing data, just 18 lakhs, or 50 per cent. on the invested capital. I need scarcely say that this return would not be immediate, but ultimate, and the period of its realization will be hastened in direct proportion to the liberality of the Government in giving the means, in men and money, required for the completion of the works. The Godavery Delta is at present depressed far below the standard of Tanjore: without roads or bridges or efficient means of culture, its population is stationary and scanty, amounting to no more than about 170 to the square mile; but every year will diminish these differences, and bring it nearer to the standard of comparison I have assumed. Even already, short though the time has been during which the influence of the works has been felt, and imperfect as their development still is, proofs of an elasticity of resources have been given full of the happiest augury for the future. There seems no reason to question the accuracy of the calculation of the Madras commissioners of public works,* whereby it is shown that the land revenue of the Rajahmundry district has been rising steadily above the average of the preceding 11 years, since 1847, the year when the works were begun, up to the present time; and that during the period reviewed by them, the gross increase has exceeded 19 lakhs of rupees, or 190,000*l.*, being very nearly 7 lakhs, or 70,000*l.*, more than the actual amount of expenditure incurred by Government up to the same date (1850-51) in carrying out the scheme of irrigation to its extent at that time.

It is not, however, to the influence of irrigation solely that this remarkable and progressive advance is to be attributed. The whole social fabric sympathises with the ebb and flow of agricultural progress; the capital circulated in the district to promote the latter, gave a new impetus to the general power of production; all trades felt it, an increased consumption of taxable articles was perceptible, and the general revenue sprung up at once under the new stimulus of constant employment, and regular payment to large masses of the population in the hitherto poverty-stricken district. What the effect of continued agricultural progress will be on the general revenue may be estimated by again referring to the parallel case of the Cauvery Delta. The general revenue from all sources in this tract may be estimated at present as not less than 54 lakhs of rupees, or 540,000*l.* per annum. That from the Delta of the Godavery, with its superior natural capabilities, reaches only to 30 lakhs, or 300,000*l.*, at the very extreme.

* Report, para. 261, page 102.

A total increase in the latter of 24 lakhs, or 240,000*l.*, may therefore be finally anticipated, of which 19½, or 195,000*l.*, may be due to the land, and 4½, or 45,000*l.*, to miscellaneous sources. Viewed thus, the return on invested capital rises from 50 to between 62 and 63 per cent. The margin thus allowed is surely abundant, not only to justify the Government in advancing with the works to their fullest development, and in their most efficient and substantial style, but to encourage it in doing so. I need not multiply illustrations of the indirect results of the works on the interests of the people. These follow inevitably in the train of the advantages obtained by the State, and are in fact the sources of them. I leave the broad and undeniable fact, that on a maximum estimate of expenditure and cost of maintenance, there are undoubted grounds for anticipating an ultimate return of from 50 to 60 per cent., to speak for itself.

I have now completed my account of the great works in the Deltas of the Cauvery, the Kistnah, and the Godavery, the three central regions of agricultural improvement in the Madras Presidency. It has been shown that the projects either actually executed or in progress of execution, affect tracts of country containing in the aggregate a total area of fully 20,000 s uare miles, or 12¼ millions of acres, whereof one-half may be considered as either cultivated or culturable. This aggregate area is inhabited at present by a population numbering rather more than 4 millions of souls, whose material condition ranges from that of the utmost comfort in Tanjore to that of the utmost depression in Guntoor; but among whom one standard, and that the highest, will ultimately prevail. Of the 6 millions of acres adapted to irrigation, not less than 2 millions will have a full supply provided for them, at a cost which, in its utmost extent, cannot exceed half a crore of rupees, or half a million sterling, in the aggregate; and the annual revenue obtained by the State, on which this powerful stimulus will operate, reaches at this moment to 1¼ millions of pounds, and may be expected to advance progressively to rather more than 2 millions per annum. The million and three-quarters of people forming the population of Tanjore pay, on the average, very nearly 2½ rupees, or 5 shillings each per annum to the State. The 2 millions forming the population of Rajahmundry, Masulipatam, and Guntoor, pay similarly an equal sum. In the first case, the area of taxation amounts to 3,900 square miles; in the other it rises to nearly 17,000 miles; the sum is in the one case paid by a population amounting to 430 in the square mile, occupying a fertile, well cultivated, and well watered region, productive in the highest degree, and the payment is therefore made cheerfully, and balances in arrears are practically unknown; in the other it is paid by a population averaging not more than 130 on the square mile, poor, scattered, depressed, and the payment is therefore reluctantly made, and is a heavy burden evaded whenever practicable, and hence much in arrears. As the population of the Kistnah and Godavery Deltas rises to the standard of Tanjore, under the operation of the same causes to which this standard is due, we shall have these two regions inhabited by upwards of 7 millions of souls, instead of only 2, as at present, and as they will be far more able then than now to pay their $2\frac{1}{2}$ rupees each, as their annual contribution to the expenses of the Government, we shall have a total revenue of a crore and three-quarters, or $1\frac{3}{4}$ millions of pounds, instead of the 60 lakhs or 600,000*l.* a year we now derive from them. The ultimate income from the three Deltas, may therefore be expected, in course of time (which as I said before, but may repeat here, will *be shorter or longer according to the liberality and* earnestness of the Government in pressing forward the works to completion), to become $2\frac{1}{4}$ crores of rupees, or $2\frac{1}{4}$ millions of pounds per annum. These few details will suffice as a general outline of the aggregate results that may be anticipated from the projected works, in so far as the State is concerned; and as regards the community, advantages fully equal to those now experienced in Tanjore, but which are not so readily expressible in money, owing to the great uncertainty of the data, will assuredly be realized.

In discussing the details of these really noble works, I have endeavoured to do justice to the personal *devotion and professional skill of the officers* concerned in carrying them forward. My own experience has been gained in a part of India presenting characteristics in its surface, and hydrography, very different to those found in the Peninsula; and among works which have but a general resemblance to those described, agreeing with them in their ultimate object, but differing greatly in the manner whereby this is attained. I have tried to bear this fact always in mind in the expression of my opinions on the works, and to give their due weight to the more minute knowledge and larger experience of those who have spent their professional lives in daily familiarity with the localities. For such conclusions as are in any way opposed to those of the officers on the spot, I have been careful to state my reasons, so that they may stand or fall by their own merits. The past progress has been slow; and it was of course impossible to come so closely in relation with the works as I necessarily did without learning the various views that were taken from different points, as to the causes to which their slow development was attributed. To these, with all the personal feelings that have become linked with them, I have alluded as lightly as I possibly could, desiring rather to regard them as belonging to the past than as likely to influence the future of the works. The vigorous prosecution and final completion of these great projects must hereafter be objects of common concern to the Government, the executive officers, and the general community; for reputation or resources, on the part of each, are almost equally involved in them.

CHAPTER IV.

It only remains for me now to terminate this report by a brief reference to some examples of the tank irrigation system of Madras. In passing through the irrigated districts, I availed myself of every opportunity of inspecting such works; and among the plans forwarded to me by the kindness of the local Government, are some showing in a very clear and satisfactory way the various details of two of the finest specimens of the class, the Chumbrumbaukum and Cauverypauk tanks—the former in the Chingleput, the latter in the Northern Arcot districts. These have been prepared under the superintendence of Captain Collyer, of the Madras Engineers, an officer of large experience in the department, to whose cordial co-operation and personal kindness I owe many obligations. For minute professional details of work I would refer, as in former cases, to these plans, restricting myself here to a few general remarks on the system.

The extent to which it has been carried throughout all the irrigated region of the Madras Presidency is truly extraordinary. An imperfect record of the number of tanks in 14 districts shows them to amount to no less than 43,000 in repair, and 10,000 out of repair, or 53,000 in all. It would be a moderate estimate of the length of embankment for each to fix it at half a mile; and the number of masonry works, in sluices of irrigation, waste weirs, &c., would probably be not over-rated at an average of 6. These data, only assumed to give some definite idea of the extent of the system, would give close upon 30,000 miles of embankments (sufficient "to put a girdle round the globe" not less than 6 feet thick) and 300,000 separate masonry works. The whole of this gigantic machinery of irrigation is of purely native origin, as it is a fact that not one new tank has ever been made by us, and the concurrent testimony of those best informed on the subject shows that a great many fine works of the kind have been allowed to fall into utter disrepair and uselessness. The revenue dependent on existing works is roughly estimated at 150 lakhs or $1\frac{1}{2}$ million sterling per annum, and the capital sunk in them is materially under-rated at ten times this amount, or 15 millions.

The methods of forming these works are as varied as the accidents of the ground they occupy. Valleys are taken possession of, and the natural drainage lines flowing through them are checked by embankments sufficiently long to close the gorges, and sufficiently high to retain a volume of water proportioned to the areas of irrigation situated below them. Descending steppes of land are occupied by a succession of reservoirs, the higher feeding the lower from its surplus supply, and the whole forming one connected scheme of irrigation. Dry basin-shaped hollows have banks carried round their ridges, and supplies introduced from adjoining rivers by means of special channels; or long slopes, where the fall is considerable, have portions embanked more or less regularly on three sides, and the included space forms a storage area for such volume of water as local wants may call for, derived either from natural or artificial sources. Examples of these, and other methods which need not be dwelt upon, are to be found scattered throughout the irrigated region, and no mean skill has frequently been shown in the selection of the sites, and the adaptation of the different subsidiary works of distribution and protection to their respective purposes. I have already mentioned how great the scale is on which some of the most ancient of these reservoirs have been constructed; citing as illustrations the Ponairy in Trichinopoly, with its embankment of 30 miles in length and probable area of 60 or 80 square miles now lost to the community, and the Veeranum tank, with its 12 miles of embankments and 35 miles in area, happily still in full operation, and securing at this time, after an existence of almost fabulous duration, an annual revenue of 114,500 rupees, or 11,450*l.*, to the Government.

Instead, however, of limiting myself to generalities like the preceding, I will, from the plans before me, give some details of those two examples which have been specially selected to illustrate the system, and from these a fair idea of the practical working of the whole may be formed.

The tank which bears the rather formidable name of Chumbrumbaukum is one of the finest in the Madras Presidency. It is picturesquely situated in the vicinity of bold hilly ground, and looks like a natural lake in a position where such a sheet of water might very readily be looked for. Beyond furnishing the water and the site, however, nature has had very little to do with its creation. It is purely artificial, and its supply is retained by an embankment 3 miles 5 furlongs 20 yards in length, ranging from 9 to no less than 28 feet in thickness, and from 16 to 26 feet in height. Its area is 9½ square miles, and its volume may be estimated at 3,000 millions of cubic feet of water. It maintains a sheet of rice cultivation, nearly 10,000 acres in extent, yielding to Government an annual revenue of rather more than 50,000 rupees, or 5,000*l.*, and the cost of improving its various works and keeping them in efficient repair has averaged, during the last 20 years, about 7 per cent. on the revenue derived from it. Its apparatus for distribution consists of 10 irrigation sluices, the details of which will be understood best by reference to the plans. Its safety during floods is insured by the action of 6 waste weirs or escapes (locally termed "Calingulas"), giving in the aggregate a breadth of escape channel of 676 feet, with a depth below the crest of the embankment ranging from 6 to 13 feet according to position. Through this area an enormous mass of water can escape, and as the supply is dependent almost exclusively on natural rainfall and merely local drainage, the protective provision has proved adequate, and breaches have been very rare. The last formidable accident of this kind occurred in 1818, when, on the 3rd of January, a breach 248 feet in length, and excavated 15 feet below the natural surface of the ground, was made, and through it the whole volume of the tank was poured upon the lower lands.

The origin of the catastrophe was traced to the failure of one of the ancient irrigation sluices, which was very injudiciously placed, and had been gradually undermined by the action of the water. This, however, was substantially repaired, and the other works of the same kind strengthened and improved, so that from that period up to the present time no similar mishap has been experienced, and the works are all now in excellent order.

The Cauverypauk tank differs essentially from that just described, in being independent of local rains, by its supply being derived from the Pellar river, a stream carrying a large volume of water during the season of culture: it is even more purely artificial than the preceding, there being no hills or broken ground in the vicinity which could have been taken advantage of. Its antiquity is great, and it is only a few years ago, that in taking down one of the ancient masonry sluices, an inscription was found upon it, showing that it had been in operation 400 years, during which period the bed of the tank had clearly been raised 12 feet by gradual deposits of mud or sand; the tank itself is doubtless far older than even this.

The length of the Cauverypauk embankment is 3¾ miles, the area of the tank about 7 square miles, and its greatest water-spread nearly 2 miles. The bank is revetted along its entire length with stone, sometimes in very massive but roughly-squared blocks, and without mortar, except at a few spots; the revetment wall is 6 feet thick at bottom, 3 feet at top, and 22 feet in height. The earthen embankment behind this wall rises 5 or 6 feet higher, and in 1849 its top was fixed uniformly about 9 feet above high water-mark. The breadth is nowhere less than 12 feet at top, with a front slope of $2\frac{1}{2}$ horizontal to 1 perpendicular, and a rear slope of $1\frac{1}{2}$ to 1. The whole surface is carefully turfed or planted with a grass, the roots of which are an excellent means of strengthening the soil.

The supplying channel is about 7 miles in length, originally most tortuous, but now much improved in this respect: it is provided with adequate escapes to regulate the volume of water admitted into the reservoir, and besides filling this it supplies two smaller tanks close to it, having an area of about a square mile.

The extent of land irrigated from the Cauverypauk tank is nearly 7,700 acres, yielding to Government an annual revenue of a little more than 58,000 rupees, or 5,800*l*. The water is distributed from 9 masonry sluices, of which details will be found in the plans; and as the irrigated land lies 20 feet below the ordinary level of the water in the tank, the supply is of course delivered all over it with perfect ease. The safety of the tank is insured by the action of two waste weirs, of the combined length of nearly 580 feet, with a depth of from 4 to 6 feet for the passage of the surplus water. These have proved efficient in preserving the tank from actual breach; but it has occasionally been very nearly subjected to an accident of this kind.

One of the most formidable causes of injury to tanks having such water-spreads as those under description, is found in the action of the waves on the embankments during gales. Even with moderate winds the force thus generated is, as I have had opportunities of witnessing personally, an enemy of a very serious order. The action is counteracted by long slopes in front or on the water face of the bank, and protective coverings of rough stone, either with or without mortar, the latter being, I believe, the best method where material is abundant.

In October 1836 the Cauverypauk tank was nearly destroyed during a tremendous gale, which rose so suddenly that no previous precaution could be taken to guard against its effects by opening the waste weirs. The waves washed over the embankment, cutting it away and forming deep ravines in rear of it, until at the deepest part of the tank a thickness of only about 3 feet of earth intervened between the country below and the mass of water above the bank. The probabilities against the safety of the work were excessive, and had the scale been turned against it by any one of several very likely contingencies, the results would have been fearful, for the bursting of the Cauverypauk tank would inevitably have entailed the bursting of every other reservoir of the kind between it and the coast, including that of Chumbrumbaukum, previously described, as they could not possibly have contained the additional volume that would have been thrown into them, filled to overflowing as they already were by the same rain-storm. The accumulated contents of all these basins would have been poured into the city of Madras through the adjoining river channels, themselves previously full from bank to bank; and the fatal consequences to life and property must have been most deplorable. The risk was sufficient to justify the most vigorous measures of repair and protection. The embankments of the Cauverypauk tank were carefully strengthened and raised throughout; the old waste weir was so remodelled as to make its action more effective and its management easier than they were in its ancient form, and a new escape was added with a waterway of 275 feet. These measures have hitherto been successful in preventing any recurrence of the danger formerly experienced.

The tank system of Madras being, as I have already mentioned, essentially native in its origin and nearly all its details, does not present unobjectionable models for introduction elsewhere. The examples I have given are, however, among the best types of the class; and the professional details shown in the plans present ideas that might be usefully adopted by ourselves. We have many rivers of the same spasmodic character as those of the Carnatic, and other regions of tank irrigation—the whole series of sub-Himalayan torrents and local drainage lines in the Northern Doab and Central India belong to the class; but as yet we have done little to utilize their waters, though what we have done has proved very encouraging. That a tank system is destined to grow up in connection with and subservient to our local canal system I have not a doubt, and I believe that we shall yet economize, if not the whole, certainly a large portion of that volume now running waste every season through districts to which its retention would be the greatest of boons; we may not find it expedient to adopt all the details of the Madras plans, but they cannot fail to be instructive, and some of them may occasionally be applicable in practice.

I cannot close my report without reverting for a moment to the field of improvement presented by the Presidency of Madras in the single department of irrigation. In all parts of India profit to the State and the people follows, as certainly as effect follows cause, the provision of an abundant supply of water for agricultural purposes; but in Madras the results go far beyond the general average. The staple of agriculture in the irrigated districts being rice, the want of water brings with it abject poverty and discontent; its abundance, wealth and contentment. Every acre that is newly watered passes at once from the revenue rate of dry, to that of wet cultivation, guaranteeing to the Government an immediate return paid with far greater ease to the cultivators of the land than the lower tax leviable before. The return is immediate, and its amount great. I have almost hesitated in adopting the data given by the Madras Commissioners of Public Works, so extravagantly large do they appear. But they are statements founded on official returns, open to verification, and unlikely to be seriously in error. When these show returns varying from a minimum of 77 to a maximum of 259 per cent. on the original cost of the works, it is unconceivable that fields paralleled only, if paralleled at all, by those of Australia and California can be left much longer unwrought. Whether the pictures given to us in public documents of the state of the people and the country, except in a few favored localities, be correct or not, it is certain that the Government of Madras cannot increase its resources in any more certain, or more legitimate, or more profitable way than by extending over the length and breadth of the territories under its control, the means of turning to useful account the vast volumes of water which are annually poured into the sea through hundreds of now useless channels. I have spoken in this report only of those tracts which I have seen and judged of for myself. But other authorities equally trustworthy, and, from local knowledge, far more competent, bear testimony to the rich capabilities of other regions than those of the Cauvery, the Kistnah, and the Godavery, to which my own observations have been confined; and I only hope that the results in these, most successful as they have been even already, may ensure the steady progress of that course of improvement of which they are the first and most encouraging evidences.

Having returned from Masulipatam to Madras on the 15th of February, and thus completed a palankeen journey of nearly 1,500 miles, since my first arrival at Madras on New Year's Day, I awaited the arrival of the Overland steamer, which came in on the 26th, and brought me to Calcutta on the 3rd of March, thus terminating the duties which had been assigned to me by the Honorable the Court of Directors.

19th October, 1853.

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