

## Irrigation in India and Egypt

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on the one side and the Public Works policy on the other, that whatever affects one or the other is soon felt among surveyors. Unhappily this state of affairs may last for some time ; it may be a period of several months, or even years. But it is to be hoped that whenever confidence is restored—and a British naval victory in the North Sea would go a long way to restore it—business will begin to resume its normal conditions ; and Australia, with her vast natural resources, will no doubt quickly recover from the temporary depression.

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## Town Planning.

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A special lantern lecture will be delivered on Friday, 4th September at 8 o'clock, in St. James' Hall, Phillip Street, Sydney, by Mr. W. R. Davidge, F.S.I., etc., to engineers, architects, surveyors, and others specially interested.

A lecture on the same subject will be delivered by Mr. Charles C. Reade, organiser and secretary to the Australasian Town Planning Tour, at the same hall on Friday, the 18th September.

We trust members will take advantage of these excellent opportunities of learning what is being done on the other side of the world.

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## Irrigation in India and in Egypt.

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(*Popular Science Lecture* by PROFESSOR W. H. WARREN, M.INST.C.E., LL.D., etc., delivered at a meeting of the Royal Society of New South Wales, October 16th, 1913.

### INTRODUCTORY.

Irrigation is of very ancient origin, and it appears to have been practised in Mesopotamia and Egypt several thousand years before the Christian Era. The earliest form was probably a natural inundation system brought about by rivers overflowing their banks and flooding the lands bordering on their lower reaches. This appears to have been the origin of the Basin System, which has been so largely practised in Egypt, and which, in the time of Joseph, made it the principal producer of corn for the adjoining countries.

Rivers such as the Nile in Egypt and those in Northern India having seasons of periodic flood, generally have their source in the mountain ranges where the rainfall is heavy and the formation rocky. The stream is at first torrential in character, and flows rapidly down the steep slopes carrying with it material eroded from its bed and the sides of the valley in which it flows. The slope becomes less steep and the velocity less rapid as it approaches the foot of the hills where

the heavier material carried in suspension is deposited. The river flows in a more or less deep channel through the flatter country in its course towards the sea, gradually diminishing in velocity and increasing in width until it reaches at length the region where it overflows its banks in times of flood. The material hitherto carried in suspension is deposited, gradually raising the level of the bed and banks and spreading its silt on the adjacent lands. The object of the basin system is to control and regulate these periodic inundations, and consists of forming a chain of basins on the land bordering on the river by constructing suitable embankments, regulators and canals.

Some such system of control may have been applied to the Tigris and Euphrates in Mesopotamia, but the great prosperity and fertility of Babylonia appear to have been due to a more advanced system of irrigation. According to the Bible, and to a record said to be older, it appears that Hammurabi, one of the kings of Babylonia, made a canal and constructed branch canals distributing the water over the desert plains. The inscription describing these ancient works existed 2200 B.C., and it states that the water supply was unfailing, thus implying that the canals were what we now call perennial.

So that the system of perennial canals which has been so successfully introduced into India by British engineers probably owes its origin to the hydraulic engineers of ancient Chaldea.

#### IRRIGATION IN INDIA.

It appears that far back in ancient history man has devised many systems for carrying water to land under cultivation in order to increase the fertility of the soil, and in no country is this ancient system of irrigation better exemplified than in India.

The Hindu races were probably mainly responsible for the introduction of irrigation in India, and the extent to which it was and is still practised, is governed by the deficiency or abundance of the rainfall and the supply of water carried by the rivers and watercourses of the country. The methods resorted to by the natives of India for obtaining water for irrigation purposes were by means of wells, storage tanks, and inundation canals derived from rivers. An inundation canal can only be supplied with water when the river is in flood; it has no regulating devices for controlling the supply, so that its utility depends upon the fixed volume, regular periodicity and duration of the river floods. These canals, together with wells, were the only means of irrigation available in ancient times in the Punjab and Scinde. In the southern district of the Madras Presidency, where the rainfall is small and uncertain, an enormous number of artificial reservoirs or tanks has been constructed for the storage of water, many of these are of great antiquity. According to Colonel F. H. Rundall, C.S.I., R.E., about 60,000 of these tanks are provided with masonry works. The Madras tanks depend mainly on local rainfall, but they are sometimes supplied from rivers or streams by means of channels taking off above weirs constructed in the beds of rivers. In a Government Report it is stated that there are 1,129 weirs across rivers or streams in Madras, each connected with a series of tanks, or with a single one. The larger weirs of irrigation works, such as the delta systems, are not included in the numbers stated.

The natives of India appear to have possessed considerable skill in the construction of embankments of earth for forming tanks and anicuts across rivers, which, although developed to a greater extent in Madras, existed more or less in other parts of India. In the tract of land between the Ganges and the Jumna, now commanded by the Ganges Canal, there existed, in 1860, 70,000 masonry wells, and 280,000 temporary earthen ones, irrigating 1,479,000 acres by lift. Some of these are still in existence. Again, in many of the larger rivers are to be found the remains of ancient anicuts or weirs of somewhat crude construction, but generally well located in regard to the purpose intended. Some of these have been restored and are still in use, but the annual cost of repairs is excessive. Hence it is clear that irrigation in India is of ancient origin, and it was necessary for the British engineers in the first place to study the works they found in that country, and the conditions which influenced their inefficiency, before they could apply successfully their greater skill and scientific knowledge to the design and construction of those greater irrigation works now so widely distributed throughout the Indian Empire.

#### MECHANICAL APPLIANCES FOR RAISING WATER.

The ancient methods used by the natives of India and Egypt for raising water from wells and lowlying-depressions consist of the following :—

(1) The Persian Wheel ; (2) the Mote ; (3) the Piccottah in India (called the Shadouf in Egypt) ; (4) the Basket ; (5) the Doon.

All along the banks of the Nile one sees the numerous shadoufs at work lifting water from the river into channels leading to the areas under cultivation. The Persian Wheel is called a sakia in Egypt, and is generally actuated by bullocks. These ancient and somewhat crude devices have been used for raising water in India and Egypt for thousands of years, and they are apparently just the same to-day.

In Egypt there is a considerable number of pumping plants used for lifting water and for drainage of the low-lying land on portions of the delta.

The methods of obtaining water from rivers for irrigation consists of inundation and perennial canals. In regard to the inundation canals the site for the entrance taking off from the river should be carefully selected, the object being to reduce the deposit of silt in the canals and convey as much of it as possible to the lands to be irrigated, as the deposits from the flood waters of silt-bearing rivers are most valuable fertilising agents.

In the almost rainless districts of the Punjab and the Scinde in India, considerable areas of land are irrigated by numerous inundation canals derived from the Indus and its tributaries.

Perennial canals supply the areas irrigated, not merely in flood time, but whenever necessary, enabling the district to be more fully cultivated and with greater certainty than would be possible by the intermittent system of inundation canals.

There are two types of perennial canals :—

- (a) Those which draw their supplies from the upper portions of rivers and convey the water to the lower parts of their valleys, frequently over long distances.

- (b) Those which start from a deltaic river at the head of the delta and irrigate the low-lying lands lying between, and for some distance on the other side of the diverging branches of the river.

Examples of the first kind in India are :—The Upper Ganges Canal system taking off the river at Hardwar ; the Lower Ganges Canal systems taking off at Narora lower down the river ; the Agra Canal taken from the right bank of the Jumna at Okla about eight miles of Delhi. These are in the United Provinces of Agra and Oudh.

In the Punjab there are some fine examples of perennial canals, including the following :—The Bari Doab Canal, taking off the upper portion of the Ravi at Madhopur ; the Chenab Canal, irrigating the Rechna Doab, between the Ravi and the Chenab taking off at Khanke a few miles below Wazirabad ; the Sidhnai Canal taking off the lower portion of the Ravi near its junction with the Chenab, which is partially perennial.

Examples of the second kind, which start from the head of deltaic rivers, occur in the Province of Madras, as Dowlaishwaram, near Rajahmundry, at the head of the Godavery Delta ; the Kistna system of canals, taking off at the head of the delta at Bezvada ; the Cauvery system of canals, taking off the rivers Coleroon and Cauvery near Trichinopoli ; the canals taking off just above the Delta Barrage in Egypt, which irrigate the delta.

The foregoing systems of perennial canals are fine examples of their kind, and they will be mainly considered in regard to their efficiency in supplying water to irrigate the land under cultivation. They are all artificial channels supplied from rivers, giving an ample supply of water, and are separated into branches, each of which is provided with major or minor channels supplying directly the water courses connected with the irrigated areas. Great care is necessary in designing these canals in order that they may fulfil their purpose efficiently and economically, and the proper site and nature of the head works are of the greatest importance.

The head works consist of a weir across the river provided with under sluices. The entrance to the canal is through head sluices for regulating the supply of water. The main objects of a weir across the river are to raise the level of the water in the dry season, when the river is low, and to provide a means of forcing it through the head sluices of the canal. The under sluices, which are constructed in the weir itself, are necessary to create a scour during the flood season to keep a definite channel open above the weir in the neighbourhood of the canal head, so that there may be no difficulty in leading the water to the head sluices when the river is low.

In India weirs are divided into six classes :—(1) Founded on rock ; (2) in the boulder formation at the head of rivers near the hills. ; (3) in clay or kunkur soils. (4) On sand overlying clay or rock which can be reached in a reasonable depth ; (5) on coarse sand of very great depth ; (6) on fine sand on very great depth.

The perennial system in Egypt has been rendered possible by the construction of the Assuan Dam, which has been thickened and heightened recently so as to provide a storage of about 2,420,000 cubic metres of water. All the flood waters of the Nile pass through the

sluices of this great dam, and during the months extending from November to March the sluices are closed and the reservoir filled. During the months of April, May, June, and a part of July, the reservoir is drawn upon to supplement the deficient discharge of the river. Extensive areas of the basin system have been converted to the perennial system, producing two crops a year, with considerable advantage to the prosperity of Upper Egypt. Two important river regulators have been built between Assuan and Cairo. The Assiut Barrage, which is constructed just below the head works of the Ibrahimia Canal, and the Esna (or Isna) Barrage, between Luxor and Assuan. The Assiut Barrage has been built across the Nile to regulate the supply of the Ibrahimia Canal, and it is designed to hold up a head of 2.55 metres. The Ibrahimia Canal head is designed to withstand a head of 3.25 metres.

#### THE ASSUAN DAM.

This great work is built across the Nile at the first cataract. The dam is 6,400 feet long, or about  $1\frac{1}{4}$  miles. As stated in a report by the Director-General of Irrigation Works in Egypt, Mr. Murdock Macdonald, C.M.G., M.Inst.C.E., there were three distinct phases in the construction of this dam, as it now stands. (1) The building of the original dam; (2) the protection of the rock faces down stream, and (3) the thickening and heightening of the dam.

As originally built the height was only 85 feet, and the area impounded 863,000 acre feet. This work is principally remarkable as being the only solid dam which passes the discharge of a large river like the Nile through its body, for which purpose it is provided with 140 low-level sluices, each 23 feet deep by  $6\frac{1}{2}$  feet wide, and 40 upper sluices  $11\frac{1}{2}$  feet deep by  $6\frac{1}{2}$  feet wide. The lower sluices were designed to be capable of passing the largest possible flood with a relatively small head of water on the up-stream side of the dam. The upper sluices were built for the purpose of discharging under low heads the normal river when the reservoir is full.

The Government of Egypt, in consequence of antiquarian agitation regarding the temples of Philæ, agreed not to build the dam higher than 85 feet (106.00 R.L.) which produced a volume of 980,000,000 cubic metres, as this height, while submerging some of the outer works and colonnades of Philæ, left the main temples high and dry. The requirements of Egypt, however, were not fully met by the original dam, and it became absolutely necessary to provide additional storage-area.

When the dam was originally under construction the temples on the island of Philæ were, where necessary, carefully underpinned down to solid rock, and although the depth of water about these temples is increased by seven metres, there appears to be no reason to doubt their stability. A few other temples of minor importance in Nubia will be affected by the increased depth of water in the reservoir.

Before proceeding with the thickening and heightening of the dam it became necessary to strengthen the aprons on the down-stream side in order to resist the erosion of the granite bed of the river immediately below the dam. The effect of such an enormous volume of water flowing through the sluices at a high velocity has rendered necessary the construction of a heavy masonry floor set in 2 to 1 cement mortar,

and at present the work is satisfactory, and likely to remain so. The thickening and heightening of the dam were begun after the talus, or apron, had been completed. Sir Benjamin Baker came to the conclusion that the only satisfactory method of building the thickening in contiguity to the old dam, so as to form the whole into as homogeneous a structure as rubble masonry built in such a climate would permit, was to keep the old and the new parts separate until such time should elapse as might permit of the new work reaching the same temperature stage as that of the old part, when the space between could be filled with cement grout consisting of 1 of water to 1.2 of Portland cement.

The Grand Barrage, or Delta Barrage, as it is more frequently called, is situated at the head of the delta north of Cairo. It was originally built by a French engineer, M. Mogel, but it failed to hold up even a moderate head of water. The failure was due to careless construction, rather than to the design. It consists of two separate works across the heads of the two branches of the river—the Damietta and the Rosetta. There are three main canals which take off above the barrage, which with numerous branches, irrigate the delta. The restoration of this great work was undertaken by Sir J. Fowler and Sir B. Baker, and consisted in lengthening the aprons of masonry up and down stream, covering the old floor with a layer of concrete four feet thick over which was laid a pavement of ashlar masonry under the arches and over a portion of the down-stream apron; also a row of piles was added to the up-stream apron. The foundations of the barrage were further consolidated by means of cement grout under pressure. By means of these additions the barrage was able to hold up 4 metres, but it was decided to reduce this to 3 metres, and subsidiary weirs were constructed on both branches of the river below the barrage which hold up  $3\frac{1}{2}$  metres, or the total head held up was  $6\frac{1}{2}$  metres. In this way more perfect control has been obtained over the water at the apex of the delta during all seasons. The Menufia regulator, at the head of the Central Canal, is a fine specimen of its kind.

The Zifta Barrage, built across the Damietta branch, is a typical example of a river regulator, and embodies the experience gained in the construction of similar works elsewhere.

The United Provinces of Agra and the Oudh, the Madras Presidency and also the Punjab, in India, furnish some magnificent examples of irrigation works.

In the former the Ganges upper and lower systems of perennial canals are the most important. The upper Ganges Canal takes off just above the sacred town of Hardwar, where the river emerges from the Sewalic Hills at the foot of the Himalayan Mountains. The lower Ganges takes off at Narora, where a fine weir has been constructed.

On both systems of canals there are many very interesting works, such as the Ranipur and Puthri super passages, for passing mountain torrents across the canal, the Solani Aqueduct, carrying the canal across the Solani Valley, the Dhanauri level crossing. All these are on the Upper Ganges system. On the Lower Ganges Canal there is a remarkably fine aqueduct called the Kali Nadi, or Nadrai.

The most modern and one of the finest of the great perennial systems is the Chenab Canal, which irrigates the country known as

the Rechna Doab, between the Ravi and the Chenab Rivers. A weir has been constructed across the Chenab at Khanke 4,000 feet long, with very fine under-sluices, which keep the channel clear in front of the head works of the canal. The canal has a full discharge of 10,800 cusecs, or more than ten times that of the main canal at Berembad on the Murrumbidgee. The area irrigated is 2,000,000 acres, and the population supported is 1,000,000. The training works on the Chenab River are on a grand scale, and represent the system of river training adopted in the Punjab. The Bell-bunds on the Chenab and the tee-headed groins on the Ganges are worthy of careful study.

In Southern India the Delta systems are the most interesting, and all these, with the exception of the Mahanadi in Orissa, are situated in the Madras Presidency. The essential conditions between the ordinary conditions of Northern and Southern India is that in the north there is a perennial supply fed from the melting snows of the Himalayan Range, restricting the area under cultivation by a fixed and more or less limited supply of water, whereas in the south the main crops are grown at the time when the rivers are at their maximum volume, and frequently the south is subjected to drought. Throughout the whole Madras Presidency, in every valley, some arrangements exist for the conservation of water, which is utilised to the last drop.

The principal Delta systems are the Godavery and the Kistna, lying between Coconada and Pedda Gangan, on the east coast; they adjoin one another and form an extensive and connected irrigation area about 200 miles long by 50 miles wide. Both the Godavery and Kistna rivers break through the line of the Eastern Ghats, within fifty miles of the sea, and in the course of ages have built up the wide stretch of delta lands beyond them.

The head of the Godaveri Delta is at Dowlaishwaram, about four miles from the Railway station, Rajahmundry. A weir, designed by Sir Arthur Cotton, has been constructed across the river where the total width from bank to bank is three and a half miles, but four islands reduce the length of the weir to two and a half miles. The river Godavery drains 115,570 square miles, and has a maximum discharge of over 1,000,000 cusecs. The rise of flood at the weir is 27 to 28 feet; the bed of the river is pure sand.

At the head of the Delta there are four channels; of these the two eastern ones unite again almost immediately, and form what is called the Gowtami-Godavari; and the two western channels similarly unite to form three Vasista-Godavari. The land between these two principal branches forms the central delta, and that lying to the east of the Gowtami-Godavari forms the Eastern Delta; also the land lying to the east of the Vasista-Godavari forms the Western Delta.

The weir is 14 feet in height, and the three sets of head sluices gives a total area of 654½ square feet. The development of the various canals and distributary channels in the three sections of the delta was undertaken gradually, and to-day the system is one of the largest and most successful in India, returning over 20% on the capital invested.

The Kistna Delta system was designed by Sir Arthur Cotton soon after the construction of the Godavari Weir. The Kistna Weir is about 3,000 feet long, with a total length of 4,000 feet, including

the under sluices, and is constructed at a narrow portion of the river where a spur of sandstone runs down to the bed of the river at each side of the weir. The site for the weir was selected on account of the excellent supply of good stone immediately available from the rocky hills on each side. On each flank of the weir scouring sluices are provided in order to keep a clear channel in front of the regulating sluices of the two main canals, where they take off. The flood waters rise nearly 20 feet above the weir crest, with a velocity of eleven miles an hour.

The Kistna Canals have a total length of main line and branches of 325 miles, of which 284 miles are navigable. There are 1,614 miles of distributing channels commanding 800,000 acres. Like that of the Godavari, this system gives exceedingly good financial returns. The various head works to the canals, and the under sluices in the river in the Godavari and Kistna systems are excellent examples of their kind. There are some fine examples of under sluices at Shaha-topo Anicut.

The most interesting reservoir scheme of irrigation in India is the Periyar system in Madras. This work was designed to irrigate the district of Madura, in Southern India, where the rainfall is scanty and uncertain, and where famines have frequently occurred. This district was formerly watered by the river Vaigai, which draws its supply from a catchment area on the eastern side of the Ghats, and irrigation has been in operation from time immemorial. On the Western side of the Ghats the rainfall is copious and secure, but it passed down the Periyar Channel to the sea unutilised.

On one portion of the course of the Periyar it is only a few miles from one of the tributaries of the Vaigai, and the project consisted in diverting the surplus waters of the Periyar through the hills which intervene between it and the Vaigai. A reservoir was constructed by Colonel Pennycuik, R.E., by means of a concrete dam 1,241 feet long and 155 in height, a tunnel cut in rock through the intervening hills 5,704 feet long, having a cross-sectional area of 90 square feet and a fall of 1 in 75, discharges the water into the tributary of the Vaigai.

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## The Battle of the Gauges.

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The battle of the railway gauges, in which, unfortunately, Australia is vitally interested, is a very old story; it has been going on for many years, and many countries are still contributing their share to the fight for supremacy between the various gauges.

The warfare (says the *Indian Engineering*) commenced in Great Britain. The standard gauge of 4 feet 8½ inches had been selected by George Stephenson as the average width apart of wheels of ordinary road vehicles, and this was the gauge adopted for the Liverpool and Manchester Railway, opened for traffic in 1830. In 1833, the great Brunel persuaded the directors of the Great Western Railway to accept a gauge of 7 feet for the line from London to Bristol; and the break